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No. 41

A Dollar's Worth of Condensed Information

Jigs and Fixtures

By EINAR MORIN

PART I

BUSHINGS, LOCATING POINTS AND CLAMPING DEVICES

SECOND EDITION

Price 25 Cents

CONTENTS

Principles of Jig and Fixture Design - - - - 3
Bushings for Drill Jigs - - - - - - - - 11
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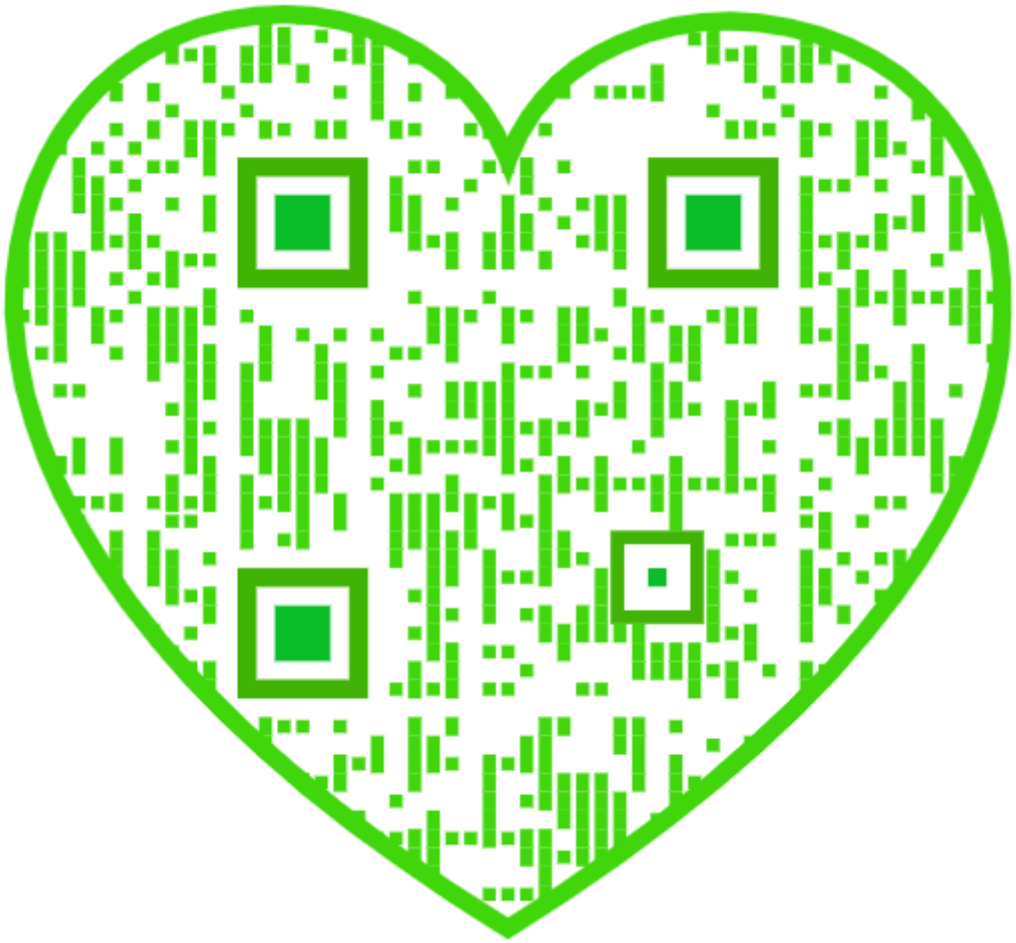

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JIGS AND FIXTURES—PART I

CHAPTER I

PRINCIPLES OF JIG AND FIXTURE DESIGN*

Jigs and fixtures may be defined as special devices made of cast iron, steel, or sometimes of wood, used in the manufacture of duplicate parts of machines, and intended to make possible interchangeable work at a reduced cost, as compared with the cost of producing each machine detail individually. The jigs and fixtures serve the purpose of holding and properly locating a piece of work while being machined, and are provided with necessary appliances for guiding, supporting, setting, and gaging the tools in such a manner that all the work produced in the same jig or fixture will be alike in all respects, even with the employment of more or less unskilled labor. When using the expression "alike," it implies, of course, simply that the pieces will be near enough alike for the purposes for which the work being machined is intended. Thus, for certain classes of work, wider limits of variation will be permissible without affecting the proper use of the piece being machined, while in other cases, the limits of variation will be so small as to make the expression "perfectly alike" literally true.

Objects of Jigs and Fixtures

The main object of using jigs and fixtures is, of course, the reduction of the cost of machines or machine details being built or made in great number. This reduction of cost is obtained in consequence of the increased rapidity with which the machines may be built, and on account of the employment of cheaper labor, which is possible when using tools for interchangeable manufacturing. Another purpose however, not less important, is the accuracy with which the work can be produced, making it possible to assemble the pieces produced in jigs without any great amount of work in the assembling department, thus also effecting a great saving in this respect.

The use of jigs and fixtures practically does away with the fitting, as this expression was understood in the old-time shop; it eliminates cut-and-try methods, and does away with the so-called patch work in the production of machinery. It makes it possible to have all the machines turned out in the shop according to the drawings, a thing which is rather difficult to accomplish if each individual machine in a large lot is built without reference to the other machines in the same lot.

The interchangeability obtained by the use of jigs and fixtures makes it also an easy matter to quickly replace broken or worn-out

* MACHINERY, April, 1908.

parts without great additional cost and trouble. When machines are built on the individual plan, it is necessary to send somebody from the shop where the machine was built to the place where it is installed, in order to fit the part replacing the broken or worn-out piece, in place, and this would, in a great many cases, involve considerable extra expense, not to mention the delay and the difficulties occasioned thereby.

As previously mentioned, jigs and fixtures permit the employment of practically unskilled labor. There are a great many operations in the building of a machine, which, if each machine were built individually, without the use of special tools, would require the work of expert machinists and toolmakers. Special tools, in the form of jigs and fixtures, permit equally good, or, in some cases, even better results to be obtained by a much cheaper class of labor, provided the jigs and fixtures are properly designed and correctly made. Another possibility for saving, particularly in the case of drill and boring jigs provided with guide bushings in the same plane, is met with in the fact that such jigs are particularly adapted to be used in multiple spindle drills, thereby still more increasing the rapidity with which the work may be produced, and, at the same time, making the machine extremely productive, so as to reduce the shop cost of this machine to a minimum. In shops where a great amount of duplicate parts are made, containing a number of drilled holes, multiple spindle drills of complicated design, which may be rather expensive as regards first cost, are really cheaper, by far, than ordinary simple drill presses.

Another point of advantage which has been gained by the use of jigs and fixtures, and which should not be lost sight of in the enumeration of the points in favor of building machinery by the use of special tools, is that the details of a machine that has been provided with a complete equipment of accurate and durable jigs and fixtures can all be finished simultaneously in different departments of a large factory, without inconvenience, thus making it possible to assemble the machine at once after receiving the parts from the different departments; and there is no need of waiting for the completion of one part into which another is required to fit, before making this latter part. This gain in time means a great deal to a manufacturing concern in cases where the orders are coming in with great rapidity, so as to require the utmost speed in production. This rapidity was entirely impossible under the old-time system of machinery building, when each part had to be made in the order in which it went on the finished machine, and each consecutive part had to be lined up with each one of the previously made and assembled details. Brackets, bearings, etc., had to be drilled in place, often with ratchet drills, which, of course, was a slow and always inconvenient operation.

Difference between Jigs and Fixtures

To exactly define the word "jig," as considered apart from the word "fixture," is rather difficult, as the difference between a jig and a fixture is oftentimes not very easy to decide. The word jig is frequently,

although incorrectly, applied to any kind of a work-holding appliance used in the building of machinery, the same as, in some shops, the word fixture is applied to all kinds of special tools. As a general rule, however, we can say that a jig is a special tool, which, while it holds the work, or is held on the work, at the same time also contains guides for the respective tools to be used, whereas a fixture is only holding the work while the cutting tools are performing the operation on the piece, without containing any special arrangements for guiding these tools. The fixture, therefore, must, itself, be securely held or fixed to the machine on which the operation is performed, hence the name. A fixture, however, may sometimes be provided with a number of gages and stops, although it does not contain any special devices for the guiding of the tools.

The definition given, in a general way, would therefore define jigs as special tools used particularly in drilling and boring operations, while fixtures, in particular, would be those special tools used on milling machines, and in some cases, on planers, shapers, and slotting machines. Special tools used on the lathe may be either of the nature of jigs or fixtures, and sometimes the special tool is actually a combination of both, in which case the expression drilling fixture, boring fixture, etc., is in place.

Fundamental Principles of Jig Design

Before entering upon a discussion of the minor details of the design of jigs and fixtures, we will briefly outline the fundamental principles of jig and fixture design. Whenever a special tool is made up for a component part of a machine, it is almost always required that a corresponding jig be made up for the place on the machine, or other part, where the first-mentioned detail is placed. It is, of course, absolutely necessary that these two jigs be perfectly alike, as to the location of guides and gage points. In order to get the holes and guides in the two jigs in perfect alignment, it is advisable, and almost always cheaper and quicker, to transfer the holes or the gage points from the first jig made, to the other. In many instances, it is possible to use the same jig for both parts. Instances where the one or the other of these principles is applicable will be shown later in the detailed descriptions of drill and boring jigs. There are also cases where it is not advisable to make up two jigs, one for each of the two parts, which are to fit together. It may be that it is impossible to properly locate the jig on one of the parts to be drilled, or it may be that if the jig were made, it would be so complicated that it would not be economical. Under such conditions the component part, itself, may be used as a jig, and the respective holes or slots in this part used as guides for the tools when machining the machine details into which it fits. Guide bushings for the drills and boring bars may then be placed in the holes in the component part itself. In many cases, drilling and boring operations are also being done, to great advantage, by using the brackets and bearings already assembled and fastened onto the machine body as guides.

One of the most important questions to be decided before making a jig is the amount of money which can be expended on a special tool for the operation required. In many cases, it is possible to get a highly efficient tool by making it more complicated and more expensive, whereas a less efficient tool may be produced at very small expense. To decide which of these two types of jigs and fixtures should be designed in each individual case depends entirely on the circumstances. In any well-managed shop there should be a careful comparison of the present cost of carrying out a certain operation, the expected cost of carrying out the same operation with an efficient tool, and the cost of building that tool itself. Unless this is done, it is likely that the shop is burdened with a great number of special tools and fixtures which, while they may be very useful for the production of the parts for which they are intended, actually involve a loss. It is readily seen how foolish it is to make up an expensive jig and fixture for a machine or a part of a machine, that would only have to be duplicated a few times. In some cases, of course, there may be a gain in using special devices in order to get extremely good and accurate results.

Locating and Clamping Devices

Regarding the design of the jig, the most important requirements are that good facilities be provided for locating the work, and that the piece to be machined may be easily inserted and quickly taken out of the jig, so that no unnecessary time is wasted in placing the work in position on the machine performing the work. In some cases, a longer time is required for locating and binding in place, the piece to be worked upon, than is required for the actual machine operation itself. In all such cases the machine performing the work is actually idle the greater part of the time, and, added to the loss of the operator's time, is the increased expense for shop cost, incurred by such a condition. For this reason, the question of locating and binding the work in place quickly, and at the same time accurately, should be carefully studied by the designer before any attempt to design the tool is made. In choosing the locating surface or points of the piece or part, consideration must be given to the facilities for locating the corresponding part of the machine in a similar manner. It is, of course, highly important that this be done, as otherwise, although the jigs may be alike, as far as their guiding appliances are concerned, there may be no facility for locating the corresponding part in the same manner as the one already drilled, and while the holes drilled thus may coincide, other surfaces also required to coincide may be considerably out of line. For this reason, one of the main principles of location is that two component parts of the machine should be located from corresponding points and surfaces.

If possible, special arrangements should be made in the design of the jig so that it is impossible to insert the piece in any but the correct way. Mistakes are often made on this account in shops where a great deal of cheap help is used, pieces being placed in jigs upside down, or in some way other than the correct one, and work that has

been previously machined at the expenditure of a great deal of time, is entirely spoiled. Therefore, whenever possible, a jig should be made "fool-proof."

When the work to be machined varies in shape and size, as, for instance, in the case of rough castings, it is necessary to have at least some of the locating points adjustable, and placed so that they can be easily reached for adjustment, but, at the same time, so fastened that they are, to a certain extent, positive. In the following chapters different kinds of adjustable locating points will be described in detail. The strapping or clamping arrangements should be as simple as possible, without sacrificing effectiveness, and the strength of the clamps should be such as to not only hold the piece firmly in place, but also to take the strain of the cutting tools without springing or "giving."

When designing the jig, the direction in which the strain of the tool or cutters acts upon the work should always be considered, and the clamps so placed that they will have the highest degree of strength to resist the pressure of the cut.

The main principles in the application of clamps to a jig or fixture are that they should be convenient for the operator, quickly operated, and, when detached from the work, still connected with the jig or fixture itself, so as to prevent the operator from losing them, or, at least, from losing time hunting for them. Many a time, looking for lost straps, clamps, screws, etc., causes more delay in shops than the extra cost sometimes incurred in designing a jig or fixture somewhat more complicated, in order to make the binding arrangement an integral part of the fixture itself. Great complication in the clamping arrangements, however, is not advisable. Usually clamping arrangements of this kind work very well when the fixture is new, but as the various parts become worn, complicated arrangements are more likely to get out of order, and the extra cost incurred in repairing often outweighs the temporary gain in quickness of operation.

Some of the principles mentioned may seem contradictory, and in fact they are. There is, therefore, all the more reason to refer to the fact that the judgment of the designer is, in every case, the most important point in the design of jigs and fixtures. Definite rules for all cases cannot be given. General principles can be studied, but the efficiency of the individual tool will depend entirely upon the judgment of the tool designer in applying the general principles of tool design to the case in hand.

When designing the jig or fixture, the locating and bearing points for the work, and the location of the clamps must also be so selected that there is as little liability as possible of springing the piece or jig, or both, out of shape, when applying the clamps. The springing of either the one or the other part will, of course, cause incorrect results when the piece is taken out of the jig, as the work surfaces will be out of alignment with the holes drilled or the faces milled. The clamps or straps, should therefore, as far as it is possible, be so placed that they are exactly opposite some bearing point or surface on the work.

The designer must use his judgment in regard to the amount of metal put into the jig or fixture. It is desirable to make these tools as light as possible in order that they may be easily handled, be of smaller size, and cost less in regard to the amount of material used for their making, but, at the same time, it is poor economy to sacrifice any of the rigidity and stiffness of the tool, as this is one of the main considerations for efficient results. On large-sized jigs and fixtures, it is possible to core out the metal in a number of places, without decreasing, in the least, the strength of the jig itself. The corners of jigs and fixtures should always be well rounded, and all burrs and sharp edges filed off, so as to make them convenient and pleasant for handling. Smaller jigs should also be made with handles in proper places, so that they may be held in position while working, if it be a drilling jig, and also for convenience in moving the jig about.

Jigs Provided with Feet

Ordinary drill jigs should always be provided with feet or legs on all sides which are opposite the holes for the bushings, or other provisions for guiding the tools, so that the jig can be placed square on the table of the machine. These feet also greatly facilitate the making of the jig, making it much easier to lay out and plane the different finished surfaces. On the sides of the jig, where no feet are required, if the body is made from a casting, it is of advantage to have small lugs projecting out, for bearing surfaces when laying out and planing. While jigs are most commonly provided with four feet on each side, in some cases it is sufficient to provide the tool with only three feet, but care should be taken in either case that all bushings and places where pressure will be applied to the tool are placed inside of the geometrical figure obtained by connecting, by lines, the points of location for the feet.

While it may seem that three feet are preferable to use, because the jig will then always obtain a bearing on all the three feet, which it would not with four feet, if the table of the machine were not absolutely plane, it is not quite safe to use the smaller number of supports, because a chip or some other object is liable to come under one foot, and throw the jig and the piece out of line, without this being noticed by the operator. If the same thing happens to a jig with four feet, it will rock, and invariably cause the operator to notice the defect. If the table is out of true, this defect, too, will be noticed for the same reason.

General Remarks on Jig Design

One mistake, quite frequently made, is giving too little clearance between the piece to be machined and the walls or sides of the jig used for it. Plenty of clearance should always be allowed, particularly when rough castings are being drilled or machined in the jigs; besides, those surfaces in the jig which do not actually bear upon the work, are likely to be made up with some slight variation from the dimensions on the drawing, particularly in a cast iron jig, and allowance ought to be made for such differences.

In regard to the locating points, it ought to be remarked that, in all instances, these should be visible to the operator when placing the work in position, so that he may be enabled to see that the work really is in its right place. At times the construction of the piece to be worked upon may prevent a full view of the locating points. In such a case a cored or drilled hole in the jig, near the locating seat, will enable a view of same, so that the operator may either see that the work rests upon the locating point, or, if the work be very particular, so that he can get a feeler or thickness gage between the work and the locating surface, to make sure that he has got the work in its correct position. Another point that should not be overlooked is that jigs and fixtures should be designed with a view of making them easily cleaned from the chips, and provision should also be made so that the chips, as far as possible, may fall out of the jig and not accumulate on or about the locating points, where they are liable to throw the work out of its correct position, and consequently spoil the piece.

The principles so far referred to have all been in relation to the holding of the work in the jig, and the general design of the jig for producing accurate work. Provisions, however, should also be made for clamping the jig or fixture to the table of the machine, in cases where it is necessary to have the tool fixed while in operation. Small drilling jigs, for instance, are not clamped to the table, but boring jigs, and milling and planing fixtures invariably have to be firmly secured to the machine on which they are employed. Usually plain lugs, projecting out in the same plane as the bottom of the jig, or lugs with a slot in them to fit the body of T-bolts, are the common means for clamping fixtures to the table. For boring jigs, it is unnecessary to provide more than three such clamping points, as a greater number is likely to cause some springing action in the fixture. A slight springing effect is almost unavoidable, no matter how strong and heavy the jig is, but, by properly applying the clamps, it is possible to limit this springing to so small a limit as to permit it to be commercially disregarded.

When jigs are made, before they are used, they should always be tested so as to make sure that the guiding provisions are placed in the right relation to the locating points and in proper relation to each other.

Summary of Principles of Jig Design

Summarizing the principles referred to in the previous discussion, we may state the following rules as being the main points to be considered in the designing of jigs and fixtures:

1. Before planning the design of a tool, compare the cost of production of the work with present tools with the expected cost of production, using the tool to be made, and see that the cost of building is not in excess of expected gain.

2. Before laying out the jig or fixture, decide upon the locating points and outline a clamping arrangement.

3. Make all clamping and binding devices as quick-acting as possible.

4. In selecting locating points, see that two component parts of a machine can be located from corresponding points and surfaces.

5. Make the jig "fool-proof," that is, arrange it so that the work cannot be inserted except in the correct way.

6. For rough castings, make some of the locating points adjustable.

7. Locate clamps so that they will be in the best position to resist the pressure of the cutting tool, when at work.

8. Make, if possible, all clamps integral parts of the jig or fixture.

9. Avoid complicated clamping arrangements, which are liable to wear or get out of order.

10. Place all clamps as nearly as possible opposite some bearing point of the work to avoid springing.

11. Cut out all unnecessary metal, making the tools as light as possible consistent with rigidity and stiffness.

12. Round all corners.

13. Provide handles wherever these will make the handling of the jig more convenient.

14. Provide feet, preferably four, opposite all surfaces containing guide bushings in drilling and boring jigs.

15. Place all bushings inside of the geometrical figure formed by connecting the points of location of the feet.

16. Provide abundant clearance, particularly for rough castings.

17. Make, if possible, all locating points visible to the operator when placing the work in position.

18. Provide holes or escapes for the chips.

19. Provide clamping lugs, located so as to prevent springing of the fixture, on all tools which must be held to the table of the machine while in use, and tongues for the slots in the tables in all milling and planing fixtures.

20. Before using in the shop, for commercial purposes, test all jigs as soon as made.

The two principal classes of jigs are drill jigs and boring jigs. Fixtures may be grouped as milling, planing, and splining fixtures, although there are a number of special fixtures which could not be classified under any special head.

CHAPTER II

BUSHINGS FOR DRILL JIGS*

Drill jigs are intended exclusively for drilling, reaming, tapping and facing. Whenever these four operations are required on a piece of work, it is, as a rule, possible to provide the necessary arrangements for performing all these operations in one and the same jig. Sometimes separate jigs are made for each one of those operations, but it is doubtless more convenient and cheaper to have one jig do for all, as the design of the jig will not be much more complicated. Although it may be possible to make a distinction between a number of different types of drill jigs, it is almost impossible to define and to get proper names for the various classes, owing to the great variety of shapes of

Fig. 1. Typical Open Drill Jig for Gear Guard

the work to be drilled. There are, however, two general types that are most commonly used, the difference between which is really very noticeable at sight. These types may be classified as open jigs and closed jigs, or box jigs. Sometimes the open jigs are called clamping jigs, although it is difficult to see a good reason for this name. The open jigs usually have all the drill bushings in the same plane, parallel with one another, and are not provided with loose or removable walls or leaves, thereby making it possible to insert the piece to be drilled without any manipulation of the parts of the jig. These jigs are often of such a construction that they are applied to the work to be drilled, the jig being placed on the work, rather than the work being placed in the jig. The work is held to the jig (or the jig to the work) by

* MACHINERY, April and May, 1908.

straps, hook bolts or clamps. Figs. 1 and 2 show types of open drill jigs.

The closed drill jigs, or box jigs, frequently resemble some form of a box, and are intended for pieces where the holes are to be drilled at

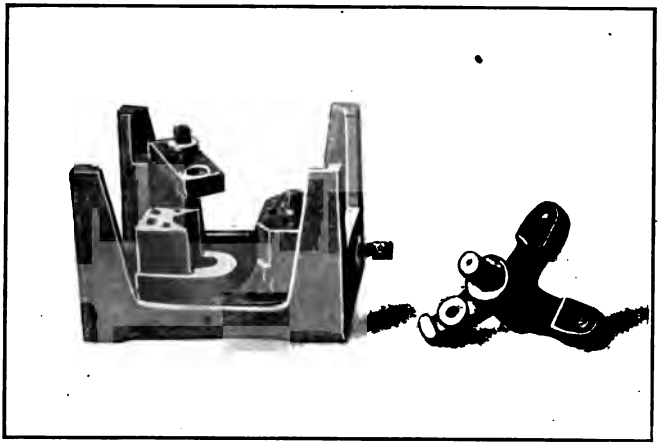

Fig. 2. Open Drill Jig, showing Commonly Used Design.

various angles to one another. As a rule, the walls are solid with the face of the jig, and the piece to be drilled can be inserted only after one or more leaves or covers have been swung out of the way. Sometimes it is necessary to remove a loose wall, which is held by screws

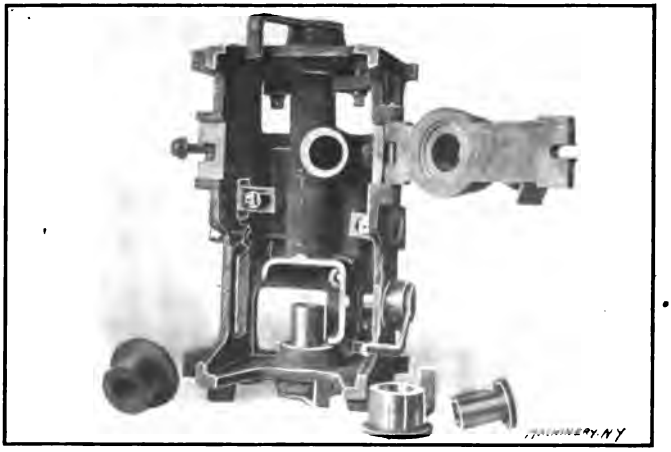

Fig. 3. Closed Drill Jig, showing Leaf opened

and dowel pins, in order to locate the piece in the jig. The work in the closed drill jig is generally held in place by set-screws and sometimes by screw bushings, as well as by straps and hook bolts. Fig. 3 shows an example of a typical closed jig. Another type of closed jig

is exemplified in a combination of drill and boring jigs, designed to serve both for drilling and boring operations.

Before designing a combination drill and boring jig, the relation between, and number of, the drilled and bored holes must be taken into consideration, and also the size of the piece to be machined. In case there is a great number of holes, it may be of advantage to have two or even more jigs for the same piece, because it makes it easier to design and make the jig, and very likely will give a better result. The holes drilled or bored in the first jig may be used as a means for locating the piece in the jigs used later on. It is plain that combination drill and boring jigs are not very well adapted for pieces of large size. In Fig. 4 is shown a typical combination jig, where the bushings for guiding the drills are indicated in the bottom surface, the work upon

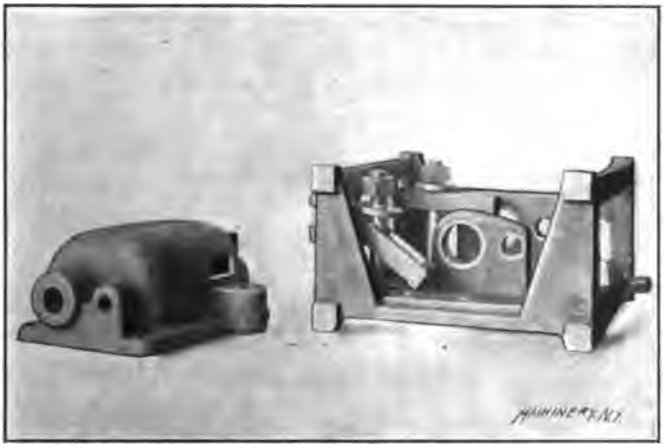

Fig. 4. Combination Drill and Boring Jig

which the operations are performed being shown at the left-hand side in the cut.

Guiding the Drill

The guides for the cutting tools in a drill jig take the form of concentric steel bushings, which are hardened and ground and placed in the jig body in proper positions. The bushings may be either stationary or removable; the latter, in the shop, are usually termed loose bushings. The most common, and the preferable form for the stationary bushing is shown in Fig. 5. This bushing is straight both on the inside and on the outside, excepting that the upper corners *A* on the inside are given a liberal radius, so as to allow the drill to enter the hole easily, while the corners *B* at the lower end of the outside are slightly rounded for the purpose of making it easier to drive the bushing into the hole, when making the jig, and also to prevent the sharp corner on the bushing from cutting the metal in the hole into which the bushing is driven.

When removable bushings are used, they should never be placed directly in the jig body unless the jig is to be used only a few times, but the jig should always be provided with a lining bushing. This lining bushing is always made of the form shown in Fig. 5. If the hole bored in the jig body receives the loose or removable bushing directly, the inserting and removing of the bushing, if the jig is frequently used, would soon wear the walls of the hole in the jig body, and after a while the jig would have to be replaced, or at least the hole would have to be bored out, and a new removable bushing made to fit the larger-sized hole resulting. In order to overcome this, the hole in the jig body is bored out large enough to receive the lining bushing referred to, which is driven in place. This lining bushing then, in turn, receives the loose bushing, the outside diameter of which closely fits the inside diameter of the lining bushing, as shown in Fig. 6, in which *A* is the jig body, *B* the lining bushing, and *C* the loose bushing. Both of these bushings are hardened and ground so that they will stand constant use and wear for some length of time. When no removable bushings

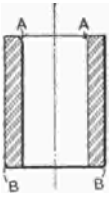

Fig. 5

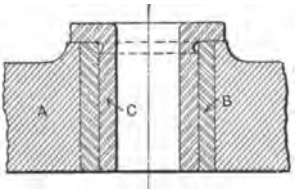

Fig. 6

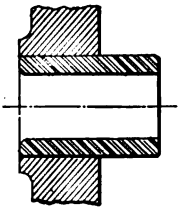

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Fig. 7

Guide and Lining Bushings for Drill Jigs

are required, the lining bushing itself becomes the drill bushing or reamer bushing, and the inside diameter of the lining bushing will then fit the cutting tool used. The bushing shown in Fig. 5 is cheaper to make, and will work fully as well when driven in place in the hole receiving it, as do bushings having a shoulder at the upper end, such as the loose bushing shown in Fig. 6. It was the practice some years ago to make all bushings with a shoulder, but this is entirely unnecessary, and simply increases the cost of making the bushing.

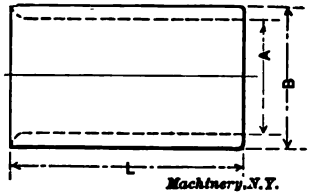
Dimensions of Jig Bushings

It is rather difficult to give any standard dimensions for jig bushings, as these depend, in most cases, on the different conditions of the various classes of jigs in which the bushings are inserted. As a rule the common practice is to make the length of the bushing twice the inside diameter of the hole in the bushing for stationary drill bushings. On very small bushings, however, say ¼ inch diameter hole and less, the length of the bushing will have to be made longer than twice the diameter, while on very large bushings the length may be made somewhat less than twice the diameter. The accompanying Table 1 gives proportions of stationary drill bushings. The dimensions, as here given, will be found suitable in all cases where no special con-

ditions demand deviation from ordinary practice. If the jig wall is thin, the bushing may project out as shown in Fig. 7, so as to give the cutting tool the proper guiding and support as close to the work as possible. In Table II are given dimensions for lining bushings, not intended to directly guide the drill, but to hold removable bushings, which in turn, guide the cutting tools. The dimensions given in Tables I and II are for bushings made from tool steel or machine steel.

While it may be, in some cases, difficult to draw a distinct line between stationary drill bushings and lining bushings, it may be said in general, that the bushings in Table I are used for guiding the drills when drilling holes directly, either with a full-sized drill, when the hole is not required to be very smooth or accurate; or, if greater accuracy

TABLE I. DIMENSIONS OF STATIONARY DRILL BUSHINGS



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A	B	L	A	B	L	A	B	L	A	B	L
$\frac{1}{16}$	$\frac{3}{16}$	$\frac{3}{8}$	$\frac{9}{16}$	$\frac{13}{16}$	$1\frac{1}{8}$	$1\frac{1}{16}$	$1\frac{7}{16}$	2	$1\frac{9}{16}$	$1\frac{15}{16}$	$2\frac{3}{4}$
$\frac{1}{8}$	$\frac{1}{4}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{7}{8}$	$1\frac{1}{2}$	$1\frac{1}{8}$	$1\frac{1}{2}$	$2\frac{1}{8}$	$1\frac{5}{8}$	2	$2\frac{7}{8}$
$\frac{3}{16}$	$\frac{5}{16}$	$\frac{5}{8}$	$\frac{11}{16}$	1	$1\frac{5}{8}$	$1\frac{3}{16}$	$1\frac{9}{16}$	$2\frac{1}{8}$	$1\frac{11}{16}$	$2\frac{1}{8}$	$2\frac{7}{8}$
$\frac{1}{4}$	$\frac{3}{8}$	$\frac{3}{4}$	$\frac{3}{4}$	$1\frac{1}{8}$	$1\frac{3}{4}$	$1\frac{1}{4}$	$1\frac{5}{8}$	$2\frac{1}{4}$	$1\frac{3}{4}$	$2\frac{1}{4}$	3
$\frac{5}{16}$	$\frac{7}{16}$	$\frac{7}{8}$	$\frac{13}{16}$	$1\frac{1}{4}$	$1\frac{7}{8}$	$1\frac{5}{16}$	$1\frac{11}{16}$	$2\frac{1}{4}$	$1\frac{13}{16}$	$2\frac{5}{16}$	$3\frac{1}{8}$
$\frac{3}{8}$	$\frac{1}{2}$	$\frac{7}{8}$	$\frac{7}{8}$	$1\frac{3}{8}$	2	$1\frac{3}{8}$	$1\frac{3}{4}$	$2\frac{3}{8}$	$1\frac{7}{8}$	$2\frac{3}{8}$	$3\frac{1}{4}$
$\frac{7}{16}$	$\frac{9}{16}$	$\frac{7}{8}$	$\frac{15}{16}$	$1\frac{1}{2}$	$1\frac{3}{4}$	$1\frac{7}{16}$	$1\frac{13}{16}$	$2\frac{3}{8}$	$1\frac{15}{16}$	$2\frac{7}{16}$	$3\frac{3}{8}$
$\frac{1}{2}$	$\frac{11}{16}$	1	1	$1\frac{5}{8}$	$1\frac{7}{8}$	$1\frac{1}{2}$	$1\frac{7}{8}$	$2\frac{3}{8}$	2	$2\frac{1}{2}$	$3\frac{1}{2}$

is required, for guiding a spotting drill which fits the bushings exactly, after which the hole is drilled out with a so-called reamer drill which is 0.010 inch or less under the size of the finished hole, and finally reamed out with a reamer fitting exactly the hole in the bushing. These bushings are thus, in general, used when no tapping or counterboring would be required. The lining bushing in Table II, again, may guide one of the tools for the holes to be finished directly, and then removable bushings are inserted to guide the other tools used.

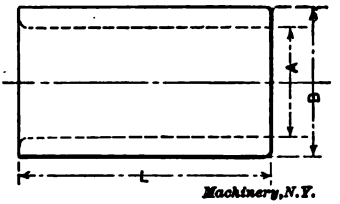
Miscellaneous Types of Drill Bushings

As already mentioned, it was, some years ago, always the practice to provide even stationary bushings with a shoulder or head, as shown in bushing *C*, Fig. 6. This will prevent the bushing from being pushed through the jig by the cutting tool, but this seldom occurs if the bushings are made to fit the tool correctly. Sometimes the shoulder is used to take the thrust of a stop collar, which is clamped on the drill, to

allow it to go down to a certain depth, as shown in Fig. 8, in which *C* is the stop collar, *D* the wall of the jig, *E* the stationary bushing, and *F*, the piece worked upon. In such a case, a shoulder on the busning may be in place.

If the work to be drilled is located against a finished seat or boss on the wall of the jig, and the wall is not thick enough to take a bushing of standard length, it is common practice to make a bushing having a long head, as shown in Fig. 9. The length *A* of the head can be extended as far as necessary to get the proper bearing. As the bushing is driven in place, and the shoulder of the head bears against the finished surface of a boss on the jig, it will give the cutting tool almost as rigid a bearing as if the jig metal surrounded the bushing all the way up.

TABLE II. DIMENSIONS OF LINING BUSHINGS



A	B	L	A	B	L	A	B	L
5/16	1/2	1/2	1 1/16	1 1/2	1 1/2	2 1/16	2 1/2	2 1/2
3/8	9/16	1/2	1 1/8	1 9/16	1 9/16	2 1/8	2 9/16	2 9/16
7/16	5/8	5/8	1 3/16	1 5/8	1 5/8	2 3/16	2 5/8	2 5/8
1/2	11/16	5/8	1 1/4	1 11/16	1 11/16	2 1/4	2 11/16	2 11/16
9/16	3/4	3/4	1 5/16	1 3/4	1 3/4	2 5/16	2 3/4	2 3/4
5/8	13/16	3/4	1 3/8	1 13/16	1 13/16	2 3/8	2 13/16	2 13/16
11/16	7/8	7/8	1 7/16	1 7/8	2	2 7/16	3	3
3/4	15/16	7/8	1 1/2	1 15/16	2 1/16	2 1/2	3 1/16	3 1/16
13/16	1	1	1 9/16	2	2 1/8	2 9/16	3 1/8	3 1/8
7/8	1 1/16	1 1/16	1 5/8	2 1/16	2 3/16	2 5/8	3 3/16	3 3/16
15/16	1 1/8	1 1/8	1 11/16	2 1/8	2 1/4	2 11/16	3 1/4	3 1/4
1	1 3/16	1 1/8	1 3/4	2 3/16	2 5/16	2 3/4	3 5/16	3 5/16
1 1/16	1 1/4	1 3/16	1 13/16	2 1/4	2 3/8	...	...	..
			1 7/8	2 5/16	2 7/16	...	...	..

Stationary or fixed drill bushings are almost invariably made from tool steel, but machine steel bushings, case-hardened and ground, give good service, and wherever it seems necessary to save in the expense of the jig, machine steel will serve the purpose well enough for any jig that is not in constant use. For large bushings in particular, the difference becomes quite considerable, and, therefore, a great many prominent firms have made it a rule to make all larger bushings and, in particular, all lining bushings of machine steel.

Removable bushings are frequently used for work which must be drilled, reamed and tapped, there then being one bushing for each of the cutting tools. They are also used when different parts of the same hole are to be drilled out to different diameters, or when the upper portion of the hole is counterbored, or when a lug has to be faced off. In this case, each tool, of course, has its own guiding bushing. The common

design of removable bushings is shown in Fig. 10. The outside is made to fit the inside of the lining bushing with a nice, sliding fit, so that it can be gently pressed into the lining bushing by the hand. The distance *A* under the head of the bushing should be the same length or longer than the guiding bushing; in the latter case, for the purpose of getting close to the work. The thickness *B* of the head varies, of course, according to the size of the bushing. The diameter *C* of the head should be from ¼ to ½ inch larger than the diameter

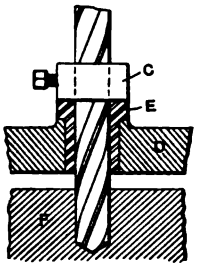


Fig. 8

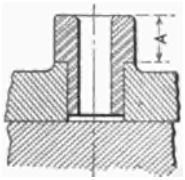


Fig. 9

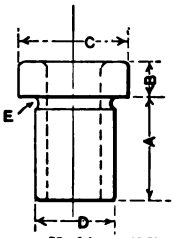


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Fig. 10

Types of Drill Jig Bushings for Different Purposes

D of the bushing. A groove *E*, ⅛ to ¼ inch wide, is cut immediately under the head, so that the emery wheel can pass clear over the part being ground.

Means for Preventing Loose Bushings from Turning

In order to prevent the bushings from turning, in some shops a collar, with a projecting tail, as shown in Fig. 11, is forced over the head of the bushing. This arrangement also makes it easy to remove

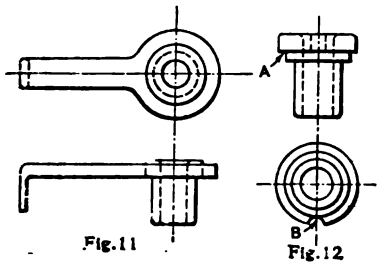

Fig. 11

Fig. 12

Fig. 13

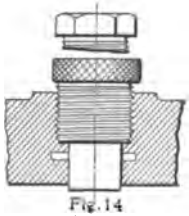

Fig. 14

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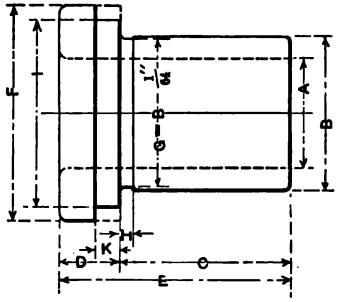
Means for Preventing Drill Bushings from Turning; Taper Bushing; and Screw Bushing

the bushing. The dog, as it is commonly called, is usually bent at the end of the tail, as shown in the cut, one end resting against some part of the jig, the proportions of which the dog must suit. Sometimes the bent end is left straight, if there is a possibility for the tail to strike against some lug in the same plane. The making of such dogs involves some extra expense, but it is very effective in avoiding troubles with the bushings turning and working their way out of the holes. In some cases simply a hole is drilled in the shoulder of the

bushing at the edge, and a corresponding pin is driven into the jig body. This serves the same purpose as the dog. It is probably cheaper, but it does not furnish the convenient means for removing the

TABLE III. DIMENSIONS OF REMOVABLE DRILL BUSHINGS



Machinery, N.Y.

A	B	C	D	E	F	H	I*	K*
½	5/16	½	⅜	⅝	⅝	⅜	½	1/16
9/16	⅜	⅝	⅜	⅝	⅝	⅜	½	1/16
⅝	7/16	⅝	⅜	⅝	⅝	⅜	½	1/16
11/16	½	⅝	⅜	⅝	⅝	⅜	½	1/16
¾	9/16	⅝	⅜	⅝	⅝	⅜	½	1/16
13/16	⅝	⅝	⅜	⅞	⅞	⅜	½	1/16
⅞	11/16	⅝	⅜	1	1	⅜	½	1/16
15/16	¾	1	⅜	1	1	⅜	⅝	1/16
1	13/16	1	⅜	1 1/16	1	⅜	⅝	1/16
1 1/16	⅞	1 1/16	⅜	1 1/8	1 1/16	⅜	⅝	1/16
1 1/8	15/16	1 1/8	⅜	1 3/16	1 1/8	⅜	⅝	1/16
1 3/16	1	1 3/16	⅜	1 1/4	1 3/16	⅜	⅝	1/16
1 1/4	1 1/16	1 1/4	⅜	1 5/16	1 1/4	⅜	⅝	1/16
1 5/16	1 1/8	1 5/16	⅜	1 3/8	1 5/16	⅜	⅝	1/16
1 3/8	1 3/16	1 3/8	⅜	1 7/16	1 3/8	⅜	⅝	1/16
1 7/16	1 1/4	1 7/16	⅜	1 1/2	1 7/16	⅜	⅝	1/16
1 1/2	1 5/16	1 1/2	⅜	1 9/16	1 1/2	⅜	⅝	1/16
1 9/16	1 3/8	1 9/16	⅜	1 5/8	1 9/16	⅜	⅝	1/16
1 5/8	1 7/16	1 5/8	⅜	1 11/16	1 5/8	⅜	⅝	1/16
1 11/16	1 1/2	1 11/16	⅜	1 3/4	1 11/16	⅜	⅝	1/16
1 3/4	1 9/16	1 3/4	⅜	1 13/16	1 3/4	⅜	⅝	1/16
1 13/16	1 5/8	1 13/16	⅜	1 7/8	1 13/16	⅜	⅝	1/16
1 7/8	1 11/16	1 7/8	⅜	1 15/16	1 7/8	⅜	⅝	1/16
1 15/16	1 3/4	1 15/16	⅜	2	1 15/16	⅜	⅝	1/16
2	1 13/16	2	½	2 1/16	2	⅜	⅝	1/16
2 1/16	1 7/8	2 1/16	½	2 1/8	2 1/16	⅜	⅝	1/16
2 1/8	1 15/16	2 1/8	½	2 3/16	2 1/8	⅜	⅝	1/16
2 3/16	2	2 3/16	½	2 1/4	2 3/16	⅜	⅝	1/16
2 1/4	2 1/16	2 1/4	½	2 5/16	2 1/4	⅜	⅝	1/16
2 5/16	2 1/8	2 5/16	½	2 3/8	2 5/16	⅜	⅝	1/16
2 3/8	2 3/16	2 3/8	½	2 7/16	2 3/8	⅜	⅝	1/16
2 7/16	2 1/4	2 7/16	½	2 1/2	2 7/16	⅜	⅝	1/16
2 1/2	2 5/16	2 1/2	½	2 9/16	2 1/2	⅜	⅝	1/16
2 9/16	2 3/8	2 9/16	½	2 5/8	2 9/16	⅜	⅝	1/16
2 5/8	2 7/16	2 5/8	½	2 11/16	2 5/8	⅜	⅝	1/16
2 11/16	2 1/2	2 11/16	½	2 3/4	2 11/16	⅜	⅝	1/16
2 3/4	2 9/16	2 3/4	½	2 13/16	2 3/4	⅜	⅝	1/16
2 13/16	2 5/8	2 13/16	½	2 7/8	2 13/16	⅜	⅝	1/16
2 7/8	2 11/16	2 7/8	½	2 15/16	2 7/8	⅜	⅝	1/16
2 15/16	2 3/4	2 15/16	½	3	2 15/16	⅜	⅝	1/16
3	2 13/16	3	½	3 1/16	3	⅜	⅝	1/16
3 1/16	2 7/8	3 1/16	½	3 1/8	3 1/16	⅜	⅝	1/16
3 1/8	2 15/16	3 1/8	½	3 3/16	3 1/8	⅜	⅝	1/16
3 3/16	3	3 3/16	½	3 1/4	3 3/16	⅜	⅝	1/16
3 1/4	3 1/16	3 1/4	½	3 5/16	3 1/4	⅜	⅝	1/16
3 5/16	3 1/8	3 5/16	½	3 3/8	3 5/16	⅜	⅝	1/16
3 3/8	3 3/16	3 3/8	½	3 7/16	3 3/8	⅜	⅝	1/16
3 7/16	3 1/4	3 7/16	½	3 1/2	3 7/16	⅜	⅝	1/16
3 1/2	3 5/16	3 1/2	½	3 9/16	3 1/2	⅜	⅝	1/16
3 9/16	3 3/8	3 9/16	½	3 5/8	3 9/16	⅜	⅝	1/16
3 5/8	3 7/16	3 5/8	½	3 11/16	3 5/8	⅜	⅝	1/16
3 11/16	3 1/2	3 11/16	½	3 3/4	3 11/16	⅜	⅝	1/16
3 3/4	3 9/16	3 3/4	½	3 13/16	3 3/4	⅜	⅝	1/16
3 13/16	3 5/8	3 13/16	½	3 7/8	3 13/16	⅜	⅝	1/16
3 7/8	3 11/16	3 7/8	½	3 15/16	3 7/8	⅜	⅝	1/16
3 15/16	3 3/4	3 15/16	½	4	3 15/16	⅜	⅝	1/16
4	3 13/16	4	½	4 1/16	4	⅜	⅝	1/16
4 1/16	3 7/8	4 1/16	½	4 1/8	4 1/16	⅜	⅝	1/16
4 1/8	3 15/16	4 1/8	½	4 3/16	4 1/8	⅜	⅝	1/16
4 3/16	4	4 3/16	½	4 1/4	4 3/16	⅜	⅝	1/16
4 1/4	4 1/16	4 1/4	½	4 5/16	4 1/4	⅜	⅝	1/16
4 5/16	4 1/8	4 5/16	½	4 3/8	4 5/16	⅜	⅝	1/16
4 3/8	4 3/16	4 3/8	½	4 7/16	4 3/8	⅜	⅝	1/16
4 7/16	4 1/4	4 7/16	½	4 1/2	4 7/16	⅜	⅝	1/16
4 1/2	4 5/16	4 1/2	½	4 9/16	4 1/2	⅜	⅝	1/16
4 9/16	4 3/8	4 9/16	½	4 5/8	4 9/16	⅜	⅝	1/16
4 5/8	4 7/16	4 5/8	½	4 11/16	4 5/8	⅜	⅝	1/16
4 11/16	4 1/2	4 11/16	½	4 3/4	4 11/16	⅜	⅝	1/16
4 3/4	4 9/16	4 3/4	½	4 13/16	4 3/4	⅜	⅝	1/16
4 13/16	4 5/8	4 13/16	½	4 7/8	4 13/16	⅜	⅝	1/16
4 7/8	4 11/16	4 7/8	½	4 15/16	4 7/8	⅜	⅝	1/16
4 15/16	4 3/4	4 15/16	½	5	4 15/16	⅜	⅝	1/16
5	4 13/16	5	½	5 1/16	5	⅜	⅝	1/16

* When using dogs as illustrated in Fig. 11, the dimensions in these columns are omitted.

bushing as does the dog. To make such a bushing more easily removable, the arrangement shown in Fig. 12 is probably the most

common. A step *A* is turned down on the head, which, in this case, will have to be a trifle larger in diameter. This step permits some kind of a tool—a screw driver, for instance, to be put underneath, and with a jerk the bushing may be lifted enough to get a good hold on it. The half-round slot at *B* is milled or filed in the periphery of the head, and fits over a pin or screw which is fastened in the jig body, as mentioned before. There are, of course, a number of other devices for preventing drill bushings from turning, but the ones shown will serve the purpose of plainly exhibiting the principles.

In Table III are given dimensions for removable bushings of the type shown in Fig. 12. As will be seen in the engraving above the table, dotted lines have been shown, indicating a shoulder without any recess of the kind shown at *A*, Fig. 12. The dimensions for a shoulder such as would result if the heads of the bushings were made to the dotted lines, apply to such bushings as are used with a dog, as shown in Fig. 11. In this case the dimensions in columns *I* and *K* in the table are omitted.

Table IV gives dimensions for bushings for holes which are reamed with a rose chucking reamer, after having first been drilled with a drill 1/16 inch smaller than the diameter of the reamer with which the hole is finally reamed out. The bushing to the extreme right, over the table, is the lining bushing, which is made of machine steel, case-hardened and ground. The bushing to the extreme left is the bushing for the rose chucking reamer. It is made of cast iron and ground. The bushing in the center is the drill bushing which is made from tool steel, hardened and ground, or in cases where it does not seem warranted to make the bushing of tool steel, of machine steel, case-hardened and ground.

The tapered removable bushing shown in Fig. 13 is objectionable on account of being expensive to make, and also on account of its liability to be thrown out of true by chips, etc., getting in between the outside of the bushing and the hole.

Screw Bushings

Sometimes removable bushings are threaded on the outside and made to fit a tapped hole in the jig, as shown in Fig. 14. The lower part of the bushing is usually turned straight, and ground, in order to center the bushing perfectly in the hole in the jig. The head of the bushing is either knurled, or milled hexagon for a wrench. When these bushings are used, they are, as a rule, not used for the single purpose of guiding the cutting tool, but they combine with this the purposes of locating and clamping the work. For such purposes they are quite frequently used. These bushings are not commonly used as removable bushings, as it would take considerable time to unscrew, and to again insert, a bushing of this type into the jig body.

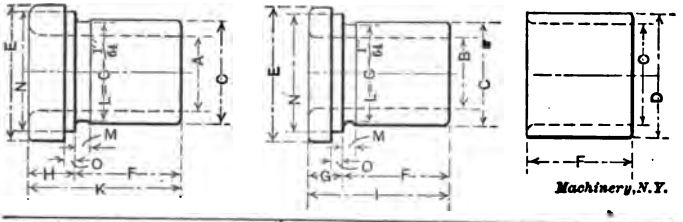
Sometimes bushings for guiding the tools may be made of cast iron, but only in such cases when the cutting tool is of such a design that it does not have any cutting edges in the bushing itself, as, for instance, in the case of guiding the smooth surface of a boring-bar,

or the shank of a reamer or a rose reamer, but hardened steel bushings must always be used when the cutting tool is liable to cut the bushing, as, for instance, in the case of drills and reamers, guided on their flutes, taps, etc.

Special Designs of Guide Bushings

When the guide bushings are very long, and consequently would cause unnecessary friction in their contact with the cutting tools,

TABLE IV. BUSHINGS FOR HOLES REAMED WITH ROSE CHUCKING REAMERS



A	B	C	D	E	F	G	H	I	K	M	N*	O*
$\frac{3}{4}$	$\frac{11}{16}$	$1\frac{1}{4}$	$1\frac{5}{8}$	$1\frac{1}{2}$	$1\frac{1}{4}$	$\frac{5}{16}$	$\frac{1}{4}$	$1\frac{7}{16}$	$1\frac{1}{2}$	$\frac{1}{8}$	$1\frac{3}{8}$	$\frac{1}{16}$
$\frac{13}{16}$	$\frac{3}{4}$	$1\frac{5}{16}$	$1\frac{11}{16}$	$1\frac{5}{8}$	$1\frac{5}{16}$	$\frac{5}{16}$	$\frac{1}{4}$	$1\frac{1}{2}$	$1\frac{9}{16}$	$\frac{1}{8}$	$1\frac{1}{2}$	$\frac{1}{16}$
$\frac{7}{8}$	$\frac{13}{16}$	$1\frac{3}{8}$	$1\frac{3}{4}$	$1\frac{3}{4}$	$1\frac{3}{8}$	$\frac{5}{16}$	$\frac{1}{4}$	$1\frac{5}{8}$	$1\frac{5}{8}$	$\frac{1}{8}$	$1\frac{5}{8}$	$\frac{1}{16}$
$\frac{15}{16}$	$\frac{7}{8}$	$1\frac{7}{16}$	$1\frac{13}{16}$	$1\frac{7}{8}$	$1\frac{7}{16}$	$\frac{5}{16}$	$\frac{1}{4}$	$1\frac{11}{16}$	$1\frac{11}{16}$	$\frac{1}{8}$	$1\frac{11}{16}$	$\frac{1}{16}$
1	$\frac{15}{16}$	$1\frac{1}{2}$	$1\frac{7}{8}$	2	$1\frac{1}{2}$	$\frac{5}{16}$	$\frac{1}{4}$	$1\frac{3}{4}$	$1\frac{3}{4}$	$\frac{1}{8}$	$1\frac{3}{4}$	$\frac{1}{16}$
$1\frac{1}{16}$	1	$1\frac{9}{16}$	$1\frac{15}{16}$	$2\frac{1}{16}$	$1\frac{9}{16}$	$\frac{5}{16}$	$\frac{5}{16}$	$1\frac{13}{16}$	$1\frac{13}{16}$	$\frac{1}{8}$	$1\frac{13}{16}$	$\frac{1}{16}$
$1\frac{1}{8}$	$1\frac{1}{16}$	$1\frac{5}{8}$	2	$2\frac{1}{8}$	$1\frac{5}{8}$	$\frac{5}{16}$	$\frac{5}{16}$	$1\frac{7}{8}$	$1\frac{7}{8}$	$\frac{1}{8}$	$1\frac{7}{8}$	$\frac{1}{16}$
$1\frac{3}{16}$	$1\frac{1}{8}$	$1\frac{11}{16}$	$2\frac{1}{16}$	$2\frac{3}{16}$	$1\frac{11}{16}$	$\frac{5}{16}$	$\frac{5}{16}$	$1\frac{15}{16}$	2	$\frac{1}{8}$	2	$\frac{1}{16}$
$1\frac{1}{4}$	$1\frac{3}{16}$	$1\frac{3}{4}$	$2\frac{1}{8}$	$2\frac{1}{4}$	$1\frac{3}{4}$	$\frac{5}{16}$	$\frac{5}{16}$	2	$2\frac{1}{16}$	$\frac{1}{8}$	$2\frac{1}{16}$	$\frac{1}{16}$
$1\frac{5}{16}$	$1\frac{1}{4}$	$1\frac{13}{16}$	$2\frac{3}{16}$	$2\frac{5}{16}$	$1\frac{13}{16}$	$\frac{5}{16}$	$\frac{5}{16}$	$2\frac{1}{16}$	$2\frac{1}{8}$	$\frac{1}{8}$	$2\frac{1}{8}$	$\frac{1}{16}$
$1\frac{3}{8}$	$1\frac{5}{16}$	2	$2\frac{1}{4}$	$2\frac{3}{8}$	$1\frac{7}{8}$	$\frac{5}{16}$	$\frac{5}{16}$	$2\frac{1}{8}$	$2\frac{3}{16}$	$\frac{1}{8}$	$2\frac{3}{16}$	$\frac{1}{16}$
$1\frac{7}{16}$	$1\frac{3}{8}$	$2\frac{1}{16}$	$2\frac{5}{16}$	$2\frac{7}{16}$	$1\frac{15}{16}$	$\frac{5}{16}$	$\frac{5}{16}$	$2\frac{3}{16}$	$2\frac{1}{4}$	$\frac{1}{8}$	$2\frac{1}{4}$	$\frac{1}{16}$
$1\frac{1}{2}$	$1\frac{7}{16}$	$2\frac{1}{8}$	$2\frac{3}{8}$	$2\frac{1}{2}$	2	$\frac{5}{16}$	$\frac{5}{16}$	$2\frac{1}{4}$	$2\frac{5}{16}$	$\frac{1}{8}$	$2\frac{5}{16}$	$\frac{1}{16}$
$1\frac{9}{16}$	$1\frac{1}{2}$	$2\frac{3}{16}$	$2\frac{7}{16}$	$2\frac{9}{16}$	$2\frac{1}{16}$	$\frac{5}{16}$	$\frac{5}{16}$	$2\frac{5}{16}$	$2\frac{3}{8}$	$\frac{1}{8}$	$2\frac{3}{8}$	$\frac{1}{16}$
$1\frac{5}{8}$	$1\frac{9}{16}$	$2\frac{1}{4}$	$2\frac{1}{2}$	$2\frac{5}{8}$	$2\frac{1}{8}$	$\frac{5}{16}$	$\frac{5}{16}$	$2\frac{3}{8}$	$2\frac{7}{16}$	$\frac{1}{8}$	$2\frac{7}{16}$	$\frac{1}{16}$
$1\frac{11}{16}$	$1\frac{5}{8}$	$2\frac{5}{16}$	$2\frac{9}{16}$	$2\frac{11}{16}$	$2\frac{3}{16}$	$\frac{5}{16}$	$\frac{5}{16}$	$2\frac{7}{16}$	$2\frac{1}{2}$	$\frac{1}{8}$	$2\frac{1}{2}$	$\frac{1}{16}$
$1\frac{3}{4}$	$1\frac{11}{16}$	$2\frac{3}{8}$	$2\frac{5}{8}$	$2\frac{3}{4}$	$2\frac{1}{4}$	$\frac{5}{16}$	$\frac{5}{16}$	$2\frac{1}{2}$	$2\frac{9}{16}$	$\frac{1}{8}$	$2\frac{9}{16}$	$\frac{1}{16}$
$1\frac{13}{16}$	$1\frac{3}{4}$	$2\frac{7}{16}$	$2\frac{11}{16}$	$2\frac{13}{16}$	$2\frac{5}{16}$	$\frac{5}{16}$	$\frac{5}{16}$	$2\frac{9}{16}$	$2\frac{5}{8}$	$\frac{1}{8}$	$2\frac{5}{8}$	$\frac{1}{16}$
$1\frac{7}{8}$	$1\frac{13}{16}$	$2\frac{1}{2}$	$2\frac{3}{4}$	$2\frac{7}{8}$	$2\frac{3}{8}$	$\frac{5}{16}$	$\frac{5}{16}$	$2\frac{5}{8}$	$2\frac{11}{16}$	$\frac{1}{8}$	$2\frac{11}{16}$	$\frac{1}{16}$
$1\frac{15}{16}$	$1\frac{7}{8}$	$2\frac{9}{16}$	$2\frac{13}{16}$	3	$2\frac{7}{16}$	$\frac{5}{16}$	$\frac{5}{16}$	$2\frac{11}{16}$	$2\frac{3}{4}$	$\frac{1}{8}$	$2\frac{3}{4}$	$\frac{1}{16}$
2	$1\frac{15}{16}$	$2\frac{5}{8}$	$2\frac{7}{8}$	$3\frac{1}{16}$	$2\frac{1}{2}$	$\frac{5}{16}$	$\frac{5}{16}$	3	$2\frac{13}{16}$	$\frac{1}{8}$	$2\frac{13}{16}$	$\frac{1}{16}$
$2\frac{1}{16}$	2	$2\frac{11}{16}$	3	$3\frac{1}{8}$	$2\frac{9}{16}$	$\frac{5}{16}$	$\frac{5}{16}$	$3\frac{1}{16}$	$2\frac{7}{8}$	$\frac{1}{8}$	$2\frac{7}{8}$	$\frac{1}{16}$
$2\frac{1}{8}$	$2\frac{1}{16}$	$2\frac{3}{4}$	$3\frac{1}{16}$	$3\frac{3}{16}$	$2\frac{5}{8}$	$\frac{5}{16}$	$\frac{5}{16}$	$3\frac{1}{8}$	$2\frac{15}{16}$	$\frac{1}{8}$	$2\frac{15}{16}$	$\frac{1}{16}$
$2\frac{3}{16}$	$2\frac{1}{8}$	$2\frac{13}{16}$	$3\frac{1}{8}$	$3\frac{5}{16}$	$2\frac{11}{16}$	$\frac{5}{16}$	$\frac{5}{16}$	$3\frac{3}{16}$	3	$\frac{1}{8}$	3	$\frac{1}{16}$
$2\frac{1}{4}$	$2\frac{3}{16}$	$2\frac{7}{8}$	$3\frac{3}{16}$	$3\frac{7}{16}$	$2\frac{3}{4}$	$\frac{5}{16}$	$\frac{5}{16}$	$3\frac{5}{16}$	$3\frac{1}{16}$	$\frac{1}{8}$	$3\frac{1}{16}$	$\frac{1}{16}$
$2\frac{5}{16}$	$2\frac{1}{4}$	$2\frac{15}{16}$	$3\frac{5}{16}$	$3\frac{9}{16}$	$2\frac{13}{16}$	$\frac{5}{16}$	$\frac{5}{16}$	$3\frac{7}{16}$	$3\frac{1}{8}$	$\frac{1}{8}$	$3\frac{1}{8}$	$\frac{1}{16}$
$2\frac{3}{8}$	$2\frac{5}{16}$	3	$3\frac{3}{8}$	$3\frac{11}{16}$	$2\frac{7}{8}$	$\frac{5}{16}$	$\frac{5}{16}$	$3\frac{9}{16}$	$3\frac{3}{16}$	$\frac{1}{8}$	$3\frac{3}{16}$	$\frac{1}{16}$
$2\frac{7}{16}$	$2\frac{3}{8}$	$3\frac{1}{16}$	$3\frac{7}{16}$	$3\frac{13}{16}$	$2\frac{15}{16}$	$\frac{5}{16}$	$\frac{5}{16}$	$3\frac{11}{16}$	$3\frac{1}{4}$	$\frac{1}{8}$	$3\frac{1}{4}$	$\frac{1}{16}$
$2\frac{1}{2}$	$2\frac{7}{16}$	$3\frac{1}{8}$	$3\frac{1}{2}$	$3\frac{15}{16}$	3	$\frac{5}{16}$	$\frac{5}{16}$	4	$3\frac{5}{16}$	$\frac{1}{8}$	$3\frac{5}{16}$	$\frac{1}{16}$
$2\frac{9}{16}$	$2\frac{1}{2}$	$3\frac{3}{16}$	$3\frac{9}{16}$	4	$3\frac{1}{16}$	$\frac{5}{16}$	$\frac{5}{16}$	4	$3\frac{3}{8}$	$\frac{1}{8}$	$3\frac{3}{8}$	$\frac{1}{16}$
$2\frac{5}{8}$	$2\frac{9}{16}$	$3\frac{1}{4}$	$3\frac{5}{8}$	$4\frac{1}{16}$	$3\frac{1}{8}$	$\frac{5}{16}$	$\frac{5}{16}$	$4\frac{1}{16}$	$3\frac{7}{16}$	$\frac{1}{8}$	$3\frac{7}{16}$	$\frac{1}{16}$
$2\frac{11}{16}$	$2\frac{5}{8}$	$3\frac{5}{16}$	$3\frac{11}{16}$	$4\frac{1}{8}$	$3\frac{3}{16}$	$\frac{5}{16}$	$\frac{5}{16}$	$4\frac{1}{8}$	$3\frac{1}{2}$	$\frac{1}{8}$	$3\frac{1}{2}$	$\frac{1}{16}$
$2\frac{3}{4}$	$2\frac{11}{16}$	$3\frac{3}{8}$	$3\frac{3}{4}$	$4\frac{3}{16}$	$3\frac{5}{16}$	$\frac{5}{16}$	$\frac{5}{16}$	$4\frac{3}{16}$	$3\frac{9}{16}$	$\frac{1}{8}$	$3\frac{9}{16}$	$\frac{1}{16}$
$2\frac{13}{16}$	$2\frac{3}{4}$	$3\frac{7}{16}$	$3\frac{13}{16}$	$4\frac{1}{4}$	$3\frac{3}{8}$	$\frac{5}{16}$	$\frac{5}{16}$	$4\frac{1}{4}$	$3\frac{5}{8}$	$\frac{1}{8}$	$3\frac{5}{8}$	$\frac{1}{16}$
$2\frac{7}{8}$	$2\frac{13}{16}$	$3\frac{1}{2}$	$3\frac{7}{8}$	$4\frac{5}{16}$	$3\frac{7}{16}$	$\frac{5}{16}$	$\frac{5}{16}$	$4\frac{5}{16}$	$3\frac{11}{16}$	$\frac{1}{8}$	$3\frac{11}{16}$	$\frac{1}{16}$
$2\frac{15}{16}$	$2\frac{7}{8}$	$3\frac{9}{16}$	$3\frac{15}{16}$	$4\frac{3}{8}$	$3\frac{1}{2}$	$\frac{5}{16}$	$\frac{5}{16}$	$4\frac{3}{8}$	$3\frac{3}{4}$	$\frac{1}{8}$	$3\frac{3}{4}$	$\frac{1}{16}$
3	$2\frac{15}{16}$	$3\frac{5}{8}$	4	$4\frac{7}{16}$	$3\frac{9}{16}$	$\frac{5}{16}$	$\frac{5}{16}$	$4\frac{7}{16}$	4	$\frac{1}{8}$	4	$\frac{1}{16}$

* When dogs illustrated in Fig. 11 are used, dimensions in these columns are omitted.

they may be recessed, as shown in Fig. 15. The distance *A*, of the hole in the bushing, is recessed enough wider than the diameter of the tool, so as not to bear on it. The length *B*, being about twice the

diameter of the hole, gives sufficiently long guiding surfaces for the cutting tool, to prevent its running out. If the outside diameter of the bushing is very large, as compared with the diameter of the cutting tool, as indicated in Fig. 16, the expense of making the bushings may be reduced by making the outside bushing of cast iron, inserting into this a hardened tool steel bushing, driven in place. The steel bushing is then given dimensions according to Table I for stationary bushings. The reason why there may be the necessity of a bushing having so large an outside diameter and so small a hole, may be that the bushing is required to be removed for counterboring part of the small hole being drilled, by a counterbore of large diameter, in which case the hole in the jig body has to be large enough to accommodate the large counterbore.

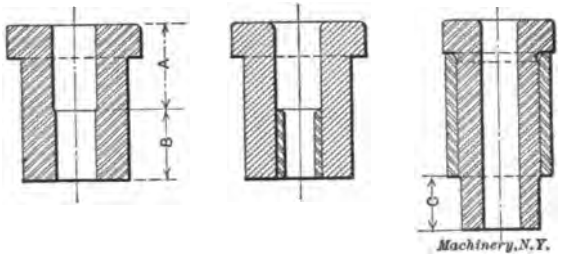


Fig. 15 Fig. 16 Fig. 17

Special Types of Drill Jig Bushings

If a loose or removable bushing is longer than the lining bushing, as illustrated in Fig. 17, it will prove advantageous to have the diameter of the projecting portion of the bushing about 1/32 inch smaller in diameter than the part of the loose bushing which fits the lining bushing. This lessens the amount of surface which has to be ground, and, at the same time, makes it easier to insert the bushing, giving it, so to say, a point, which will first enter the lining bushing, and it interferes in no way with the proper qualities of the bushing as a guide for the cutting tool.

In some cases, the holes in the piece to be drilled are so close to one another that it is impossible to find space for lining bushings in the jig. In such a case, it will be necessary to make a leaf, or a loose wall, or the whole jig, of machine steel or tool steel, hardening a portion or the whole jig thus made

CHAPTER III

LOCATING POINTS*

The locating points in a jig usually consist of finished pads, bosses, seats, or lugs, cast solid with the jig, as illustrated in Fig. 18. In this engraving the surfaces marked *f* are the locating points, which bring the piece to be machined in right relation to the bushings guiding the drills, or to the gages to which other cutting tools may be set. This way of locating the work is satisfactory when the work done is finished in a uniform way, and where there is very little variation in the parts inserted in the jig.

Another commonly used means for locating the work in jigs is by means of dowel pins, as shown at *A* and *B* in Fig. 19. The sides of the dowel pins which rest up against the work are usually flattened, as indicated, so as to give more bearing than a mere line contact with

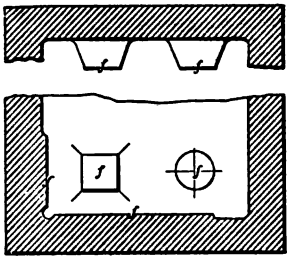


Fig. 18. Locating Pads in Jigs

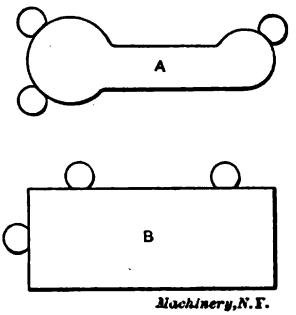


Fig. 19. Pins Used for Locating Work

the pins could give, and, at the same time prevent too rapid wear on the locating pins, as would be the case if the work bear against the pins along a line only.

Sometimes pins or studs are inserted in jigs to act as locating points, instead of having lugs cast directly on the jig as shown in Fig. 18. A case where a pin is used for this purpose is shown in Fig. 20, where *B* is the body of the jig, *A* the pin inserted to act as a locating and resting point, and *C* the work located against this point. Locating pins of this character should always be provided with a shoulder or collar, so that they will firmly resist the pressure of the work they support, without possibility of moving in the hole in which they are inserted.

A common method of locating cylindrical pieces or surfaces is that of placing the cylindrical surface in a V-block, as shown in Fig. 21. This V-block as a rule is stationary, and is held in place by screws

* MACHINERY, June, 1908.

and dowel pins, as indicated in the engraving, but sometimes these V-blocks may also be made adjustable, in order to take up the variations of the pieces placed in them, and also in order to act as clamps. A V-block of this character is shown in Fig. 22. In this, *A* is the adjustable V-block, having an oblong hole *B* to allow for the adjustment. The block is held down in place by a collar-head screw *C*,

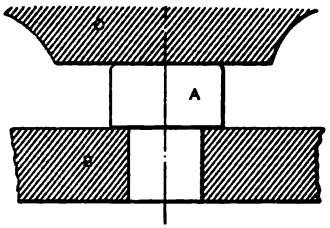


Fig. 20. Inserted Pin used for Locating and Supporting Work

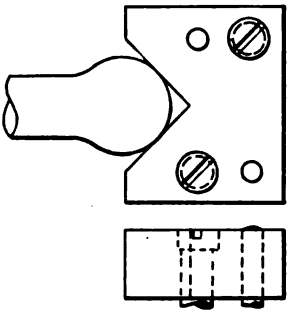


Fig. 21. V-block for Locating Round Work or Cylindrical Surfaces

which passes through the elongated hole. The under side of the block is provided with a tongue *D*, which enters into a slot in the jig body itself, the V-block being thereby prevented from turning sideways. The screw *E* passes through the wall of the jig, or through some lug, and prevents the V-block from sliding back when the work is inserted into the jig. It is also used for adjusting the V-block, and, in some cases, for clamping the work. The V-blocks are usually

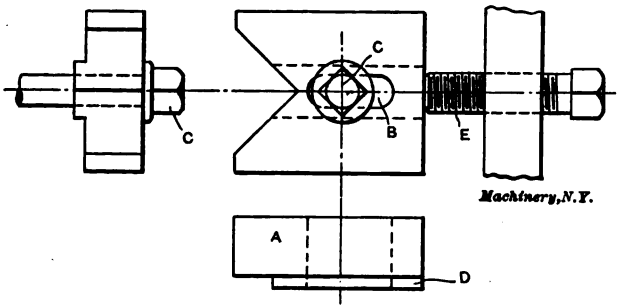


Fig. 22. Adjustable V-block used for Locating Purposes

made of machine steel, but when larger sizes are needed, they may be made out of cast iron. Little is gained, however, in making these blocks out of cast iron, as most of the surfaces have to be machined anyway, and the difference in the cost of material on such a comparatively small piece is very slight.

When it is essential that a cylindrical part of the work is located centrally either with the outside of a cylindrical surface, or with the center of a hole passing through the work, good locating means are

provided by the designs shown in Figs. 23 and 24. In Fig. 23, the stud *A* is countersunk conically to receive the work. The stud *A* is made of machine or tool steel, and may, in many cases, serve as a bushing for guiding the tool. In Fig. 24, the stud is turned conically in order to enter into a hole in the work. These two locating appliances are always made stationary, and are only used for locating the work, never for binding or clamping.

Screw Bushings and Sliding Bushings Used as Locating Means

Screw bushings of the type which has already been shown in Fig. 14, may be used for locating and clamping purposes by making them

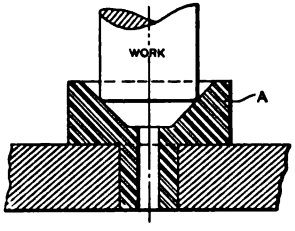


Fig. 23. Recessed Stud used for Locating Round Work

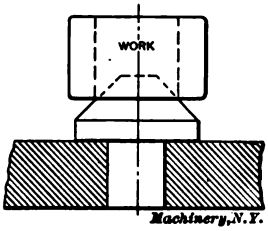


Fig 24. Conical Stud used for Locating Work in Relation to the Center of a Hole

long enough to project through the walls of the jig, and by turning a conical point on them, as shown in Fig. 25, or by countersinking them, as shown in Fig 26.

Another type of bushing which serves the same purpose as a screw bushing is illustrated in Fig. 27. This bushing, together with the forked lever *D*, and clamping bolt and wing nut shown, will serve not

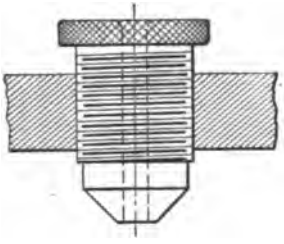


Fig. 25. Screw Bushing used for Locating Work Central with a Hole

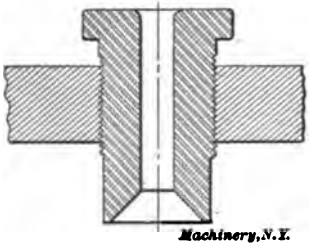


Fig. 26. Screw Bushing used for Locating Round Work by means of a Conical Recess

only to locate but also to clamp the work in place. This sliding bushing gives very good results and is preferable to the screw bushing in cases where accurate work is required, but, as a rule, where extreme accuracy would be required, this kind of bushing is not used.

In Fig. 27 the sliding bushing *A* has a close sliding fit in the lining bushing *B*. In the head of the bushing *A* there are two screws with hardened heads, which fit into elongated slots in the forked lever or yoke *D*, which, in turn, swivels around pin *E*. The eye-bolt *F* fits into a slot *G* in the yoke, and the wing nut tightens down the bush-

ing against the work as clearly indicated in the engraving. A comparatively long bearing for the bushing is required in order to produce good results. On work that varies considerably in size, this arrangement works somewhat quicker than does a screw bushing, but it is clearly in evidence that it is a rather expensive appliance, and that the construction of the jig does not always permit of its application.

In some instances it is necessary to have the screw bushing movable sideways, for instance, when the piece of work to be made is located by some finished surfaces, and a cylindrical part is to be provided with a hole drilled exactly in the center of a lug or projection, the

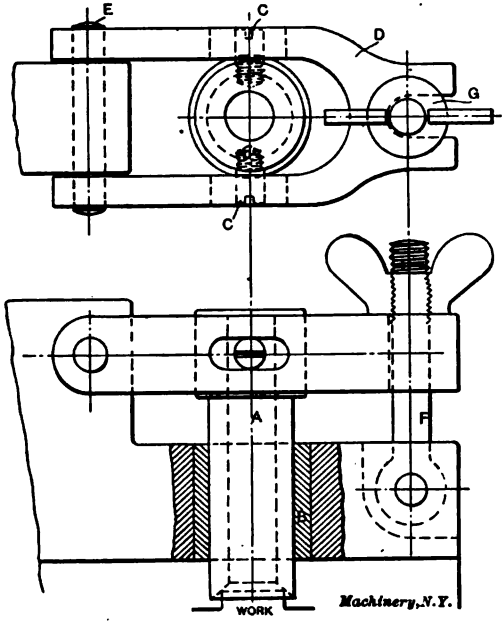


Fig. 27. Sliding Bushing for Locating and Clamping Work

relation of this hole to the finished surfaces used for locating being immaterial. The piece of work, being a casting, would naturally be liable to variations between the finished surfaces and the center of the lug, particularly if there be other surfaces and lugs to which the already finished surfaces must correspond, and in such a case, the fixed bushing for drilling a hole that ought to come in the center of the lug, might not always suit the casting. In such a case, so-called floating bushings, as shown in Fig. 28, are used. The screw bushing *A* is conically recessed, and locates from the projection on the casting. It is fitted into another cylindrical piece *B*, provided with a flange on one side. The piece *B*, again, sets into the hole *C* in the jig body *D*, this hole being large enough to permit the necessary adjustment of the jig bushing.

When the bushing has been located exactly concentric with the lug *E* on the work, the nut *F*, having a washer G under it, is tightened. It will be seen that the flange on piece *B* and the washer *G* necessarily must be large enough to cover the hole *C* even if *B* is brought over against the side of the hole. It is not often necessary, however, to use this floating bushing, because it is seldom that a drilled hole

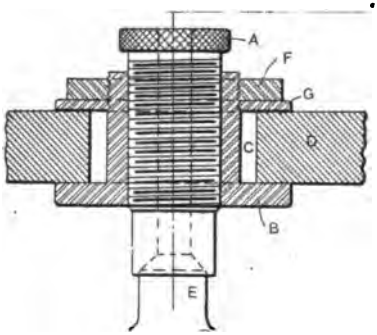


Fig 28. Floating Bushing

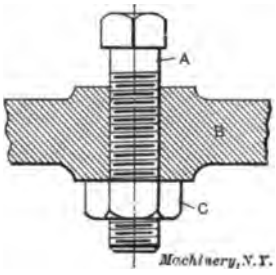


Fig. 29. Simplest Form of Adjustable Locating Point

in a piece of work can be put in without having any direct relation to other holes or surfaces.

Adjustable Locating Points

The most common form of adjustable locating points is the set-screw provided with a check nut, as shown in Fig. 29. The screw *A* is a

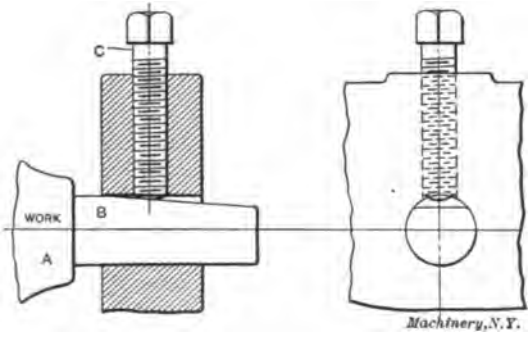


Fig. 30. Adjustable Locating Point consisting of a Flatted Stud Held in Place by a Set-screw

standard square head set-screws, or, in some cases, a headless screw—with a slot for a screw driver; this screw passes through a lug on the jig, or the jig wall itself, and is held stationary by a check nut *C* tightened up against the wall of the jig. Either end of this screw may be used as a locating point, and the check nut may be placed on either side. By using a square head screw, adjustment is very easily accomplished, but unless the operator is familiar with the intentions of the designer of the jig, locating points of this kind are often mistaken

for binding or clamping devices, and the set-screws are tightened up and loosened to hold and release the work, when the intention is that these screws should be fixed when once adjusted. It is not even possible to depend upon the check nut stopping the operator from using the screw as a binding screw. A headless screw, therefore, is preferable, as it is less apt to be tampered with.

The sliding point, as illustrated in Figs. 30 and 31, is another adjustable locating point which is used to a great extent in jig work. A flat piece of work or a plate which is not perfectly level will always rock if put down on four stationary locating points, but the difficulty thus encountered is very easily overcome by making one of the locating points adjustable, and, as a rule, the sliding point is used for this purpose.

One design is shown in Fig. 30, where *A* represents the work to be located, *B* the sliding point itself, and *C* the set-screw, binding it in

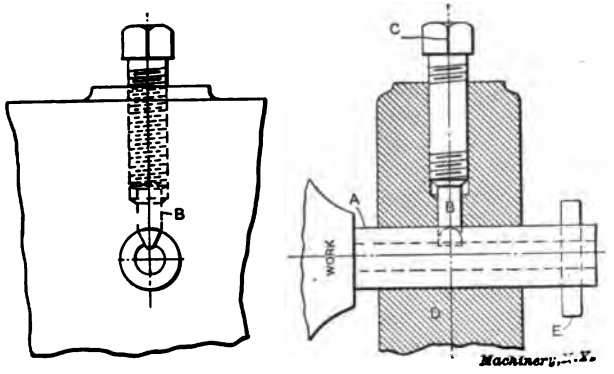
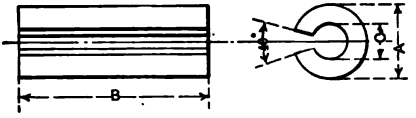


Fig. 31. Sliding Point used for Locating Work

place when adjusted. The sliding point *B* fits a hole in the jig wall and is provided with a milled flat slightly tapered, as shown, to prevent its sliding back under the pressure of the work or the tool operating upon the work. This design of sliding point is frequently used, but it is not as efficient as the one illustrated in Fig. 31. In this design the sliding point *A* consists of a split cylindrical piece, with a hole drilled through it, as illustrated in the engraving, and a wedge or shoe *B* tapered on the end to fit the sides of the groove or split in the sliding point itself. This wedge *B* is forced in by a set-screw *C*, for the purpose of binding the sliding point in place. Evidently, when the screw and wedge are forced in, the sliding point is expanded, and the friction against the jig wall *D* is so great that it can withstand a very heavy pressure without moving. Pin *E* prevents the sliding point from slipping through the hole and into the jig, when loosened, and also makes it more convenient to get hold of. In Figs. 32 and 33 are given the dimensions most commonly used for sliding points and binding shoes and wedges.

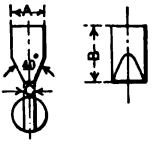
If the work to be finished in the jig has some holes already finished,

it is sometimes most satisfactory to locate the work by these holes, which may be done by means of studs or plugs similar to the one shown in Fig. 20, which then enter the holes; preferably, these studs should then be ground and hardened to the standard size of the hole. If the finished hole should be of a character that varies somewhat in size, expansion studs with bushings may be used. These studs may be of a great many different designs and styles, but, as a rule,



A	3/8	1/2	5/8	3/4
B	2¼ TO 3	2¼ TO 3	2¼ TO 3	2¼ TO 3
C	5/16	1/4	5/16	5/8

Fig. 32. Dimensions of Sliding Points



SCREWS	5/16	3/8
A	1/4	9/32
B	1/2	5/8
C	1/16	3/32

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Fig. 33. Dimensions of Shoes or Binders for Sliding Points

they always work on the same principle as the one shown in Fig. 34. In this, *A* is the bushing, fitting the finished hole in the work. This bushing is split in several different ways, either by having one slot cut entirely through it, and two more slots cut to within a short distance of the outside periphery, or by having several slots cut from the top and from the bottom, alternating, but not cut entirely through the full length of the bushing. The method of splitting,

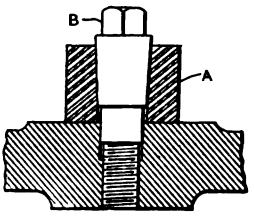
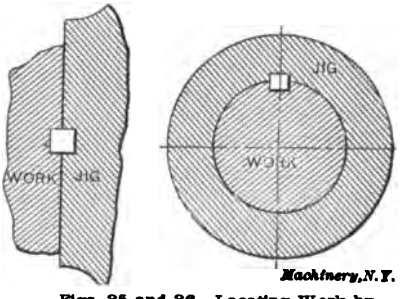


Fig. 34. Expansion Bushing used for Locating and Clamping Work



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Figs. 35 and 36. Locating Work by Keyways

however, in every case, accomplishes the same object, that of making the bushing capable of expansion, so that when the stud *B*, which is turned to fit the tapered hole in the bushing, is screwed down, the bushing is expanded.

Locating by Keyways in the Work

Sometimes the work to be finished in the jig is provided with a keyway or a slot, or with some other kind of a seat, by means of which it is located on its component part on the machine for which it is ultimately intended, and it is always essential that the work be

located in the same way in the jig as it is to be located on the machine on which it is to go; thus, if the work has a keyway, suitable for locating, a corresponding keyway ought to be put into the jig, and the work located by means of a key, as shown in Figs. 35 and 36. Instead of a loose key, a tongue may be planed or milled solid with the jig, but, as a rule, it is more satisfactory to have the loose key, as, if it should happen to wear, it is possible to replace it; and if the width of the keyway should vary in different lots of the parts made, it is possible, with little expense, to make a new key to fit the variation, whereas, if the key is made solid with the jig, and found to be either too large or too small, the trouble of fixing this would be considerably greater.

There are, of course, a variety of different methods of locating the work in the jig, depending upon the nature and the shape of the work, but those mentioned above are the most common, the cheapest, and those that, as a rule, give sufficiently good results for ordinary work. The principles involved in the design of the means of locating the work described above, would all be the same in any kind of locating devices, so that it would simply be a difference in application of the principles, rather than a difference in the principles themselves.

CHAPTER IV

CLAMPING DEVICES*

In order to hold the work rigidly in the jig, so that it may be held up against the locating points, while the cutting tools operate upon the work, jigs and fixtures are provided with clamping devices. Sometimes a clamping device serves the purpose of holding the jig to the work, in a case where the work is a very large piece and the jig is attached to the work in some suitable way. The purpose of the clamping device, however, remains the same, namely, that of preventing any shifting of the guiding bushings while the operation on the work is being performed. As has been previously mentioned, at the time when the general principles of jig and fixture design were treated in Chapter I, the clamping device should always be an integral part of the jig body in order to prevent its getting lost.

The clamping device may either directly clamp the work to the jig or *vice versa*, but very frequently the clamps simply hold in place

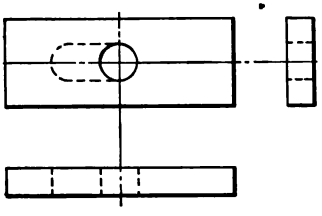


Fig. 37. Form of Clamps used in Jigs and Fixtures

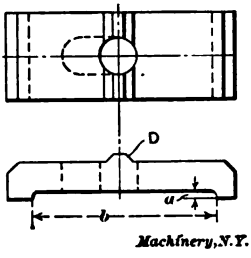


Fig. 38. Improved Form of Clamp

a loose or movable part in the jig, which can be swung out of the way to facilitate the removing and the inserting of the work in the jig. The work itself is in turn clamped by a set-screw or other means passing through the loose part, commonly called leaf. The simplest form of clamping device is the so-called clamp, of which a number of different forms are commonly used. Perhaps the most common and most reliable of all clamps is the one shown in Fig. 37. This kind of clamp is also commonly termed a strap. It is simple, cheap to make, and, for most purposes, it gives satisfactory service. The clamp shown in Fig. 38 is practically made on the same principle as the one shown in Fig. 37, but several improvements have been introduced. The clamp is recessed at the bottom for a distance *b*, to a depth equal to *a*, so as to give a bearing only on the two extreme ends of the clamp. Even if the strap should bend somewhat, on account of the pressure of the screw, it will be certain to bear at the ends, and exert

* MACHINERY, July and August, 1908.

the required pressure on the object being clamped. This strap is also provided with a ridge at *D*, located centrally with the hole for the screw, as shown in Fig. 38. This insures an even bearing of the screw head on the clamp, even if the two bearing points at each end of the clamp should vary in height, as illustrated in Fig. 39. The clamp in Fig. 37 would not bind very securely, under such circumstances, and the collar of the screw would be liable to break off, as the whole strain, when tightening the screw, would be put on one side.

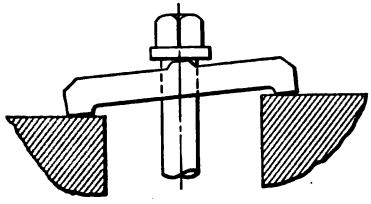


Fig. 39. Action of Clamp shown in Fig. 38 when used to Clamp Work which is not Level with the Clamping Surface

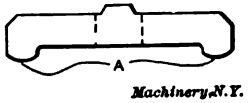
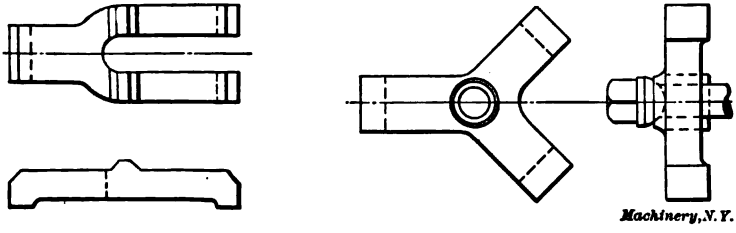


Fig. 40. Clamp shown in Fig. 38, further Improved

A still further improvement in the construction of this clamp may be had by rounding the under side of the clamping points *A*, as shown in Fig. 40. When a clamp with such rounded clamping points is placed in a position like that indicated in Fig. 39, it will practically bind the object to be held fully as firmly as if the two clamping surfaces were in the same plane.

The hole in these straps is very often elongated, as indicated by the dotted lines in Figs. 37 and 38. This allows the strap to be pulled



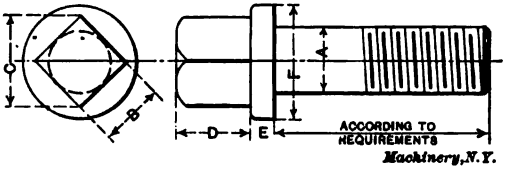
Figs. 41 and 42. Special Forms of Clamps

back far enough so as to clear the work, making it easier to insert and remove the piece to be held in the jig. In some cases, it is necessary to extend the elongated hole, as shown in Fig. 41, so that it becomes a slot, going clear through to the end of the clamp, instead of being simply an oblong hole. Aside from this difference, the clamp in Fig. 41 works on exactly the same principle as the clamps previously shown. It is evident that the clamps described may be given a number of different shapes to suit different conditions. The screws used for clamping these straps are either standard hexagonal screws or standard collar head screws, dimensions of which latter are given in Table V. In a case where it is not necessary to tighten the clamps

very much, shoulder thumb screws, as shown in Table VI, may be employed.

Instead of having the strap or clamp bear on only two points, it is sometimes necessary to have it bear on three points, in which case it may be designed similar to the strap shown in Fig. 42. In order

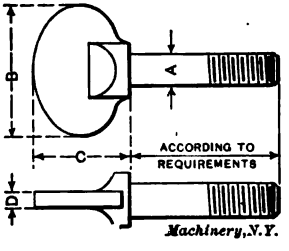
TABLE V. DIMENSIONS OF COLLAR-HEAD SCREWS



A	B	C	D	E	F	St'd No. of Threads per inch.
3/16	3/16	0.260	1/4	3/16	3/8	24
1/4	1/4	0.350	5/16	1/4	1/2	20
5/16	5/16	0.440	3/8	1/4	1/2	18
3/8	3/8	0.530	7/16	5/16	5/8	16
7/16	7/16	0.620	1/2	5/16	3/4	14
1/2	1/2	0.710	9/16	3/8	7/8	18
9/16	9/16	0.790	5/8	3/8	1	12
5/8	5/8	0.880	11/16	7/16	1 1/16	11
3/4	3/4	1.060	13/16	1/2	1 1/4	10

to get an equal pressure on all the three points, a special screw, with a half-spherical head like the one shown, may be used to advantage. The half-spherical head of this screw fits into a concave recess of the same shape in the strap. When the bearing for the screw head is made in this manner, the hole through the clamp must have plenty of clearance for the body part of the bolt.

TABLE VI. DIMENSIONS OF SHOULDER THUMB SCREWS



A	B	C	D
3/16	9/16	1/2	3/16
1/4	1	11/16	1/4
5/16	1 1/8	3/4	5/16
3/8	1 1/4	13/16	5/16
7/16	1 1/2	15/16	9/16
1/2	1 5/8	1 1/8	3/16

When designing clamps or straps of the types shown, one of the most important things to take into consideration is to provide enough metal around the holes, so that the strap will stand the pressure of the screw without breaking at the weakest place, which naturally is in a line through the center of the hole. As a rule, these straps are made of machine steel, although large clamps may sometimes be made from cast iron.

The hook bolt shown in Fig. 43 is better adapted for some classes of work than any other clamping device. At the same time, it is very easy and cheap to make and easily applied. The bolt *A* passes through a hole in the jig, having a good sliding fit in this hole, and is pushed up until the hook or head *B* bears against the work, after

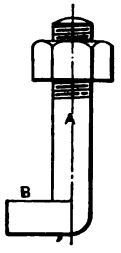


Fig. 43

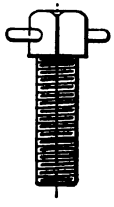


Fig. 44

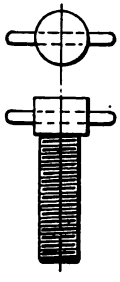


Fig. 45

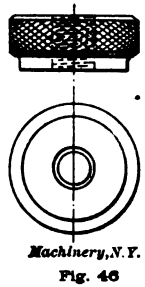


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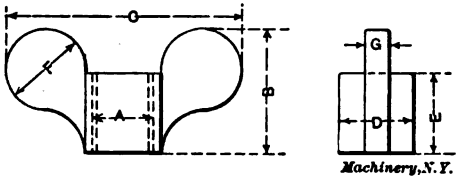
Fig. 46

which the nut is tightened. When great pressure is not required, the thumb or wing nut, such as shown, together with its dimensions, in Table VII, permits the hook bolt to be applied more readily. The thumb or wing nut is preferable to the knurled nut, shown in Fig. 46, which sometimes is used. It is possible to get a better grip, and to tighten the bolt more firmly by a wing nut than it is with a knurled

TABLE VII. DIMENSIONS OF WING OR THUMB NUTS



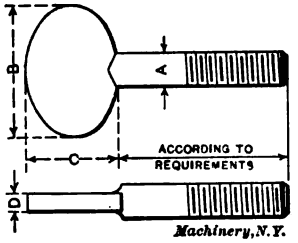
A	B	C	D	E	F	G
$\frac{3}{16}$	$\frac{5}{8}$	$1\frac{1}{8}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$
$\frac{1}{4}$	$\frac{3}{4}$	$1\frac{1}{8}$	$\frac{11}{32}$	$\frac{1}{2}$	$\frac{11}{32}$	$\frac{9}{32}$
$\frac{5}{16}$	$\frac{3}{4}$	$1\frac{1}{8}$	$\frac{11}{32}$	$\frac{1}{2}$	$\frac{11}{32}$	$\frac{9}{32}$
$\frac{3}{8}$	$\frac{13}{16}$	$1\frac{1}{16}$	$\frac{11}{32}$	$\frac{1}{2}$	$\frac{11}{32}$	$\frac{9}{32}$
$\frac{7}{16}$	$\frac{7}{8}$	2	$\frac{11}{32}$	$\frac{5}{8}$	$\frac{1}{4}$	$\frac{5}{16}$
$\frac{1}{2}$	$1\frac{1}{16}$	$2\frac{1}{4}$	$\frac{3}{4}$	$\frac{13}{16}$	$\frac{7}{8}$	$\frac{5}{16}$

nut. When the work is removed from the jig, using the hook bolt clamping device, the nut is loosened, and the head or hook of the bolt is turned away from the work, thus allowing it to be taken out, and another piece of work to be placed in position. The hook bolts are invariably made of machine steel.

In a box jig, or a jig where the work is entirely, or almost entirely, surrounded by the jig, the work is easily held in place by set-screws

and sometimes by screw-bushings. The set-screws are of different kinds, the most common being the standard square head set-screw, which is used whenever great clamping pressure is required, the square head allowing the use of the wrench. Sometimes screws of this kind may be tightened enough for the purpose by hand if a pin is put through the head of the screw, as shown in Figs. 44 and 45.

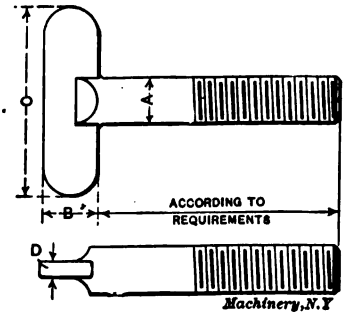
TABLE VIII. DIMENSIONS OF REGULAR THUMB SCREWS



A	B	C	D
$\frac{3}{16}$	$\frac{1}{4}$	$\frac{5}{8}$	$\frac{3}{16}$
$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{4}$	$\frac{1}{4}$
$\frac{5}{16}$	$1\frac{1}{4}$	$\frac{7}{8}$	$\frac{5}{16}$
$\frac{3}{8}$	$1\frac{1}{2}$	$1\frac{1}{8}$	$\frac{3}{8}$
$\frac{7}{16}$	$1\frac{3}{4}$	$1\frac{1}{4}$	$\frac{7}{16}$
$\frac{1}{2}$	$1\frac{7}{8}$	$1\frac{1}{16}$	$\frac{1}{2}$

This means is used not only when great pressure is not necessary, but also when the work is liable to spring if the screws are tightened too hard. In such a case, if a pin is inserted, it would be obvious that the screw head is not intended for a wrench, but that the pin is intended for getting a good grip by the hand for tightening the screw without resorting to any additional means. Usually it is not possible to use an ordinary machine wrench on such a screw, as it generally is rather thin, so that if applied to the top of the screw, it

TABLE IX. DIMENSIONS OF THUMB SCREWS WITH WIDE GRIP



A	B	C	D
$\frac{3}{16}$	$\frac{1}{4}$	$\frac{7}{8}$	$\frac{3}{16}$
$\frac{1}{4}$	$\frac{5}{16}$	1	$\frac{1}{4}$
$\frac{5}{16}$	$\frac{3}{8}$	$1\frac{1}{4}$	$\frac{5}{16}$
$\frac{3}{8}$	$\frac{7}{16}$	$1\frac{1}{2}$	$\frac{3}{8}$
$\frac{7}{16}$	$\frac{1}{2}$	$1\frac{3}{4}$	$\frac{7}{16}$
$\frac{1}{2}$	$\frac{9}{16}$	2	$\frac{1}{2}$
$\frac{9}{16}$	$\frac{5}{8}$	$2\frac{1}{4}$	$\frac{9}{16}$
$\frac{5}{8}$	$\frac{11}{16}$	$2\frac{1}{2}$	$\frac{5}{8}$

would not permit a very good grip. Of course, a monkey-wrench could be applied, but it ought to be stated in this connection that a monkey-wrench ought not to be employed in ordinary manufacturing shop work, as it is intended primarily for jobbing work. More screws probably have been tightened too hard and twisted off by the injudicious use of a money-wrench than in any other way. When a monkey-wrench is used, it should be used with discretion. This, of course, does not mean to imply that the monkey-wrench is not one of the handiest tools that a machinist ever had in his possession, but it is intended to impress the idea that unless the monkey-wrench is used

in such a manner that, when it is applied to a small screw head, the power applied at the end of the handle is in proportion to the screw, it is a risky tool to have around.

While a screw with a round head, as shown in Fig. 45, and with a pin put through the head, is undoubtedly better and more convenient to use than the one shown in Fig. 44, the latter is cheaper to make, because standard screws can be taken right from stock, and a pin hole

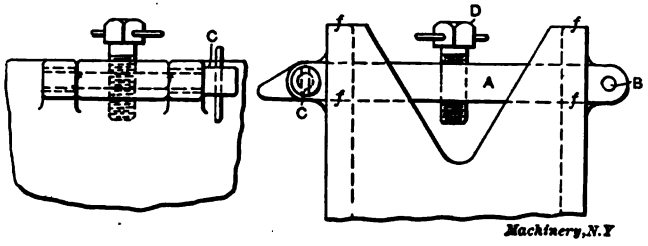


Fig. 47. Common Designs of Leaf in Drill Jigs. Screw D Clamps the Work

put through them, after the heads have been annealed. If thumb screws like the ones shown in Tables VIII and IX are available, they are preferable, as they give a good hold to the hand when they are tightened, and, besides, there is very little work required in finishing them. The use of a screw-bushing for clamping work has already been referred to. The clamping screws mentioned so far are generally applied directly onto the work, after having passed through the wall of the jig, or some projecting part serving as a seat for the screw.

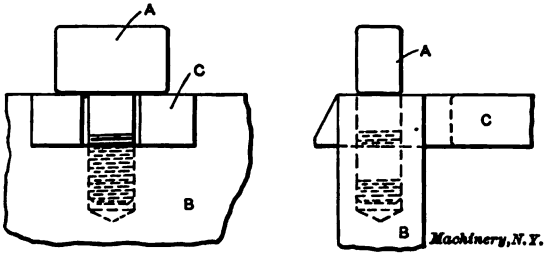


Fig. 48. Clamping Device for Leaf in Drill Jig

Loose leaves which swing out, in order to permit the work to be inserted and removed, are usually constructed in some manner similar to that shown in Fig. 47, in which *A* represents the leaf, being pivoted at *B* and held by a pin at *C*, which goes through the two lugs on the jig wall and passes through the leaf, thus binding the leaf and allowing the tightening of the set-screw *D*, which bears against the work. The holes in the lugs of the castings are lined with steel bushings in order to prevent the cast iron holes from being worn out too soon by the constant pulling out and putting in of the pin. This kind of leaf, when fitted in nicely, is rather expensive, but is used not only for binding purposes, but also for guiding purposes,

making a convenient seat for the bushings. If the leaves are fitted well in place, the bushings will guide the cutting tools firmly.

Another way of holding down the leaf is shown in Fig. 48, in which *A* is a thumb screw, screwed directly into the wall *B* of the jig, and holding the leaf *C* down, as indicated. To swing the leaf out, the thumb screw is turned back about a quarter of the turn, so that the head of the thumb screw stands in line with the slot in the leaf, this slot being made wide and long enough to permit the leaf to clear the head of the thumb screw. This is a very rapid way of clamping, and is frequently used. The lower side of the head of the screw will wear a long time before the head finally comes in line with the slot when binding. It can then easily be fixed for binding the leaf again when standing in a position where the head of the thumb screw

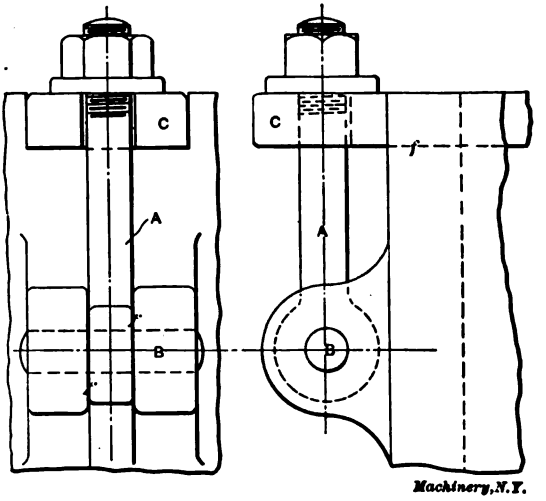


Fig. 49. Eye-bolt used for Clamping Drill Jig Leaf

is at right angles to the slot, by turning off a portion of the head on the under side. The size of these thumb screws is made according to the strain on the leaf and the size and design of the jig. No standard dimensions could be given for this kind of screw.

The hinged bolt, shown in Fig. 49, is also commonly used. Here *A* represents an eye-bolt, which is connected with the jig body by the pin *B*. The leaf or movable part *C* of the jig is provided with a slot in the end for the eye-bolt, this slot being a trifle wider than the diameter of the bolt. The threaded end of the eye-bolt is provided with a standard hexagon nut, a knurled head nut or a wing nut, according to how firmly it is necessary that the nut be tightened.

When the leaf is to be disengaged, the nut is loosened up enough to clear the point at the end of the leaf, and the bolt is swung out around the pin *B*, which is driven directly into lugs projecting out from the jig wall, a slot being provided between the two lugs, as

shown, so that the eye-bolt can swing out with perfect freedom. At the opposite end, the leaves or loose parts of the jig swing around a pin the same as in Fig. 47, the detailed construction of this end being, most commonly, one of the three types shown in Fig. 50. It must be understood that to provide jigs with leaves of this character involves a great deal of work and expense, and they are used almost exclusively when one or more guide bushings can be held in the leaf.

When the jig leaf is simply intended to hold one or more set-screws by which the work is held down, it may be made and fastened as shown in Fig. 51. In this case, the name "leaf" is rather out of place, and this fastening device becomes merely a strap. Some improvements of this kind of clamping device are shown in Fig. 52, where the ends of the strap are slotted in various ways so as to

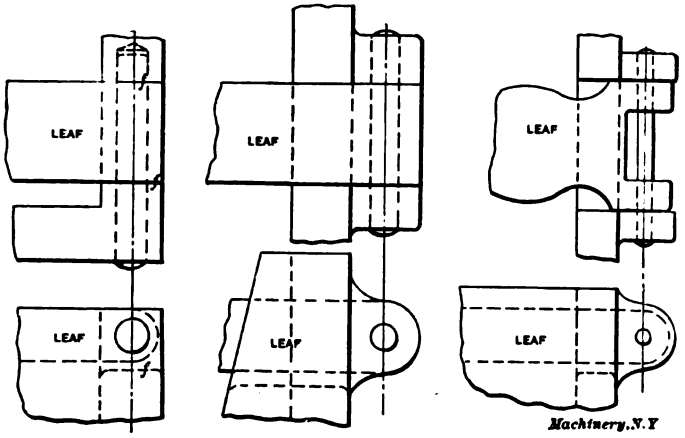


Fig. 50. Detail Designs of Joints between Leaf and Jig

permit getting the strap out of the way rapidly when the work is to be removed.

The ordinary jack-screw is employed quite commonly as a clamping device in drill jigs, but the objection to its use is that, not being an integral part of the jig, it is very apt to get lost. In Fig. 53 are shown two simple devices working on the same principle as the jack-screw, but having the advantage of being connected to the jig by the pin shown at *B*. At *A* in Fig. 53, a set-screw screws directly into the end of the eye-bolt, and at *C* a long square nut is threaded on the eye-bolt. These nuts must be made of special length, and be made up especially for this purpose. The eye-bolts are fastened, as shown, directly to the wall of the jig, and the set-screw or nut is tightened up against the work. The eye-bolt can be set at different angles to suit the work, thereby providing a clamping device which may be said to possess double adjustment. This device makes a very convenient clamping arrangement. It works satisfactorily, and has the advantage of being easily swung out of the way.

The principle of clamping work in the jig by means of a wedge or tapered gib is illustrated in Fig. 54. The work is located between the wedge *A* and the wall *B* of the jig and pressed up against the

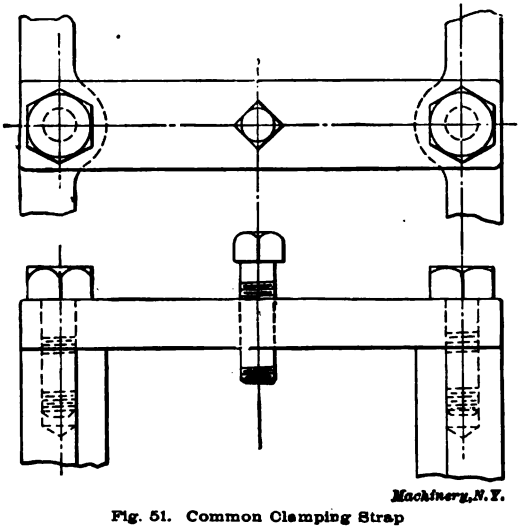


Fig. 51. Common Clamping Strap

wall by the wedge which can be driven in by a hammer, or screwed in place when the jig is constructed as shown. It is preferable to have the wedge screwed in place, as it is then less apt to be loosened by

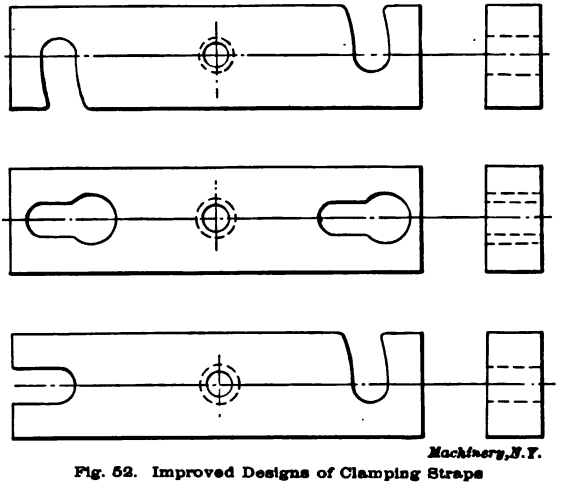


Fig. 52. Improved Designs of Clamping Straps

the constant vibrations to which it is subjected, and at the same time the wedge is less apt to get lost, being an integral part of the jig. The ear for the screw may be placed in any direction with regard to the gib, as indicated by the dotted lines in the end view of Fig. 54.

This tightening device is, in particular, adapted to work of dove-tail shape, as shown in Fig. 55. In this case the wedge is made similar to the common taper gib used for taking up the wear in dove-tail slides. It is sometimes of advantage to relieve the bearing surface opposite the wedge, as shown in dotted lines in Fig. 54, in order to

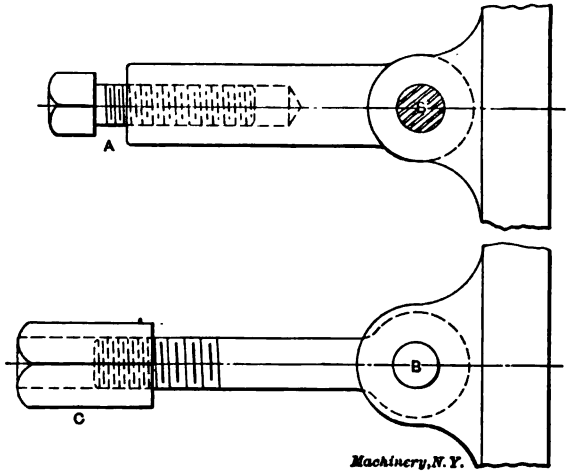


Fig. 53. Clamping Devices Working on the Jack-screw Principle

provide two distinct bearing points, which prevent the work from rocking. The hole in the ear of the gib through which the screw passes, must be oblong, so that when the screw is adjusted, and the gib moved in or out, there is ample allowance for the sidewise movement of the ear, due to the taper of the gib.

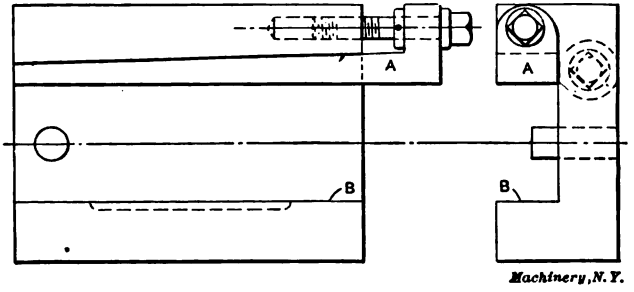


Fig. 54. Wedge or Taper Gib used for Clamping

If it is required to get a bearing on two points of a surface that is likely to vary in its dimensions, a yoke can be used, designed on the principle of that shown in Fig. 56. In the engraving, *A* is the work to be clamped, and *B* is the yoke which fits into a slot in the center of the strap or clamp *C*. The yoke is held by a pin *D*, around which it can swivel to adjust itself to the work. It is evident that the amount of pressure at the two points *E* and *F* will be equal, or at least near

enough so for all practical purposes, even though the screws at the ends of the strap may not be equally tightened. In this device the pin *D* takes the full clamping strain, and should therefore be designed strong enough, and the strap which is weakened by the slot and the hole in the center, should be reinforced, as indicated, at this place.

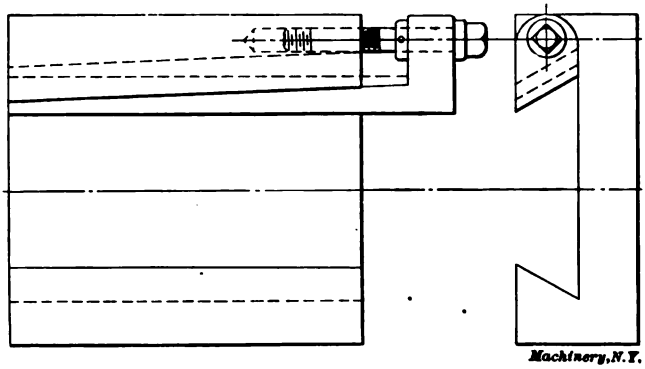


Fig. 55. Wedge used for Clamping Dove-tailed Work

It is preferable to have spiral springs at each end of the strap to prevent the strap from slipping down when the work is taken out. The strap may be made either of cast iron or machine steel, the yoke being made out of machine steel.

Eccentric clamps and shafts for binding purposes are often used. In Figs. 57 and 58 are shown two applications of the principle of the

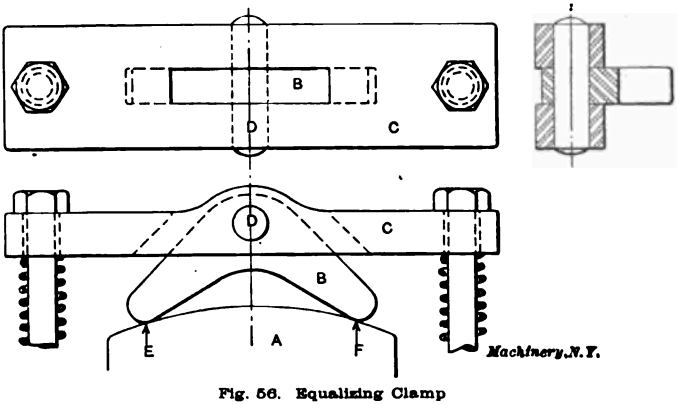


Fig. 56. Equalizing Clamp

eccentric shaft. In Fig. 57 the eccentric shaft *A* has a bearing at both ends, and the eye-bolt *B* is connected to it at the center and is forced down when the eccentric shaft is turned. This causes the two end points of the clamp *C* to bear on the work. This clamping arrangement has a very rapid action and gives good satisfaction. The throw of the eccentric shaft may vary from 1/16 inch to about

1/4 inch, depending upon the diameter of the shaft and the accuracy of the work. In cases where it is required that the clamp should bear in the center, an arrangement like the one shown in Fig. 58

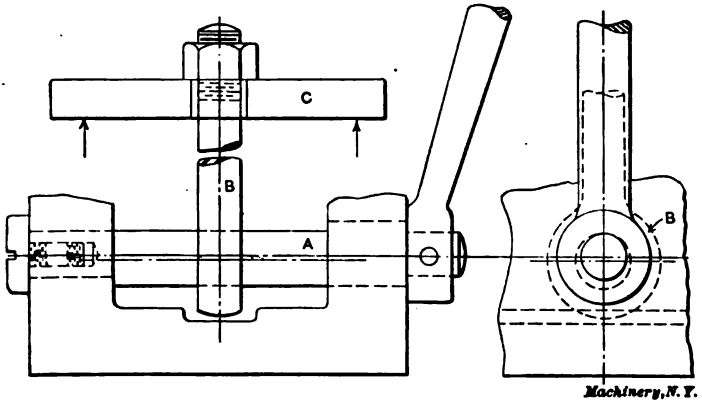


Fig. 57. Eccentric Clamping Bolt

may be used. Here the eccentric shaft *A* has a bearing in the center and eye-bolts *B* are connected to it at the ends. As the eccentricity is the same at both ends, the eye-bolts or connecting-rods will be pulled down evenly when the lever *C* is turned, and the strap *D* will get an

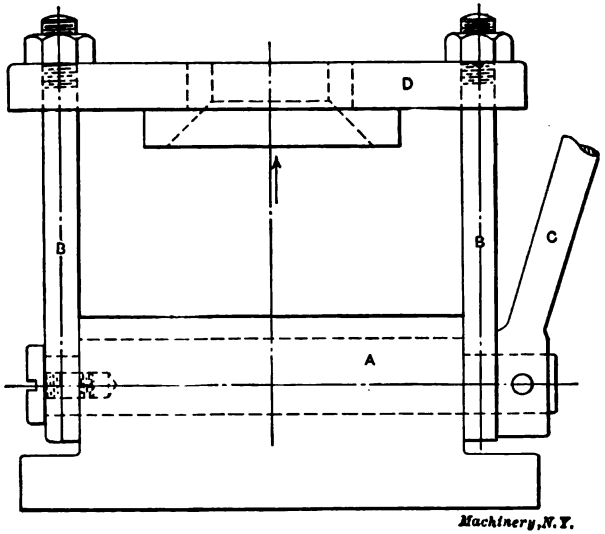
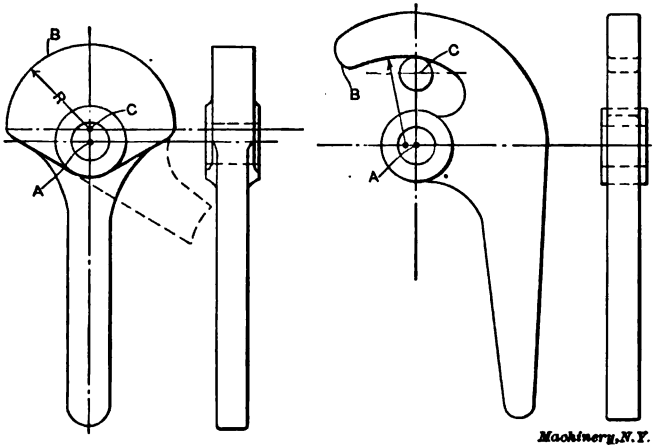


Fig. 58. Another Example of Eccentric Clamping Bolt

even bearing on the work in the center. If the force of the clamping stress is required to be distributed equally at different points on the work, a yoke like that shown in Fig. 56 may be used in combination with the eccentric clamping device in Fig. 58.

When it is essential that the strap *D* should also be used for locating purposes, necessary guides will be provided for the strap, so as to hold it in the required position. These guiding arrangements may consist of rigid rods, ground and fitted into drilled and reamed holes in the strap, or square bars held firmly in the jig, and fitted into square slots at the ends of the strap. The bars can also be round, and the slots at the ends of the strap half round, the principle in all cases remaining the same, excepting, of course, that the more rigid the guiding arrangement is, the more may the accuracy of the locating be depended upon.

The ordinary eccentric lever works on the same principle as the eccentric rods just described. There is a great variety of eccentric



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Figs. 59 and 60. Cams or Eccentrics used for Clamping

clamping devices, but they are not as commonly used in present-day jig design as they used to be a few years ago. The eccentric clamping levers, however, provide good and rapid clamping action. In Fig. 59 is shown one especially intended for clamping finished work. It is not advisable to use this kind of lever on rough castings for the reason that the castings may vary so much that the cam or eccentric would require too great a throw to rigidly clamp them. The extreme throw of the eccentric lever in general should not exceed one-sixth of the length of the radius of the eccentric arc if the rise takes place during one-quarter of a complete turn of the lever. This would give an extreme throw of say ¼ inch for a lever having 1½ inch radius of the cam or eccentric. Even to one unfamiliar with this kind of work, it is plain that, as the eccentric cam swivels about the center *A*, the lever being connected to the jig with a stud or pin, the face *B* of the cam, which is struck with the radius *R* from the center *C*, recedes or approaches the side of the work, thereby releasing it from, or clamping it against, the bottom or wall of the jig. The lever for the eccentric may be placed in any direction, as indicated by the full and dotted

lines in Fig. 59. In Fig. 60 is shown another eccentric lever, which is used frequently on small work for holding down straps or leaves, or for pulling together two sliding pieces, or one sliding and one stationary part, which in their turn hold the work. These sliding pieces may be V-blocks or some kind of jaws. The cam lever is attached to the jig body, the leaf, or the jaw, by a pin through hole *A*. The hook *B* engages the stud or pin *C* which is fastened in the opposite jaw or part, which is to be clamped to the part into which the pin through hole *A* is fastened.

The variety of design of eccentric cam levers is so great that it is impossible to show more than the principles, but the examples shown embody the underlying action of all the different designs.

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